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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

OIL FIELDS OF THE TEXAS-LOUISIANA GULF COASTAL PLAIN

BY

N. M. FENNEMAN

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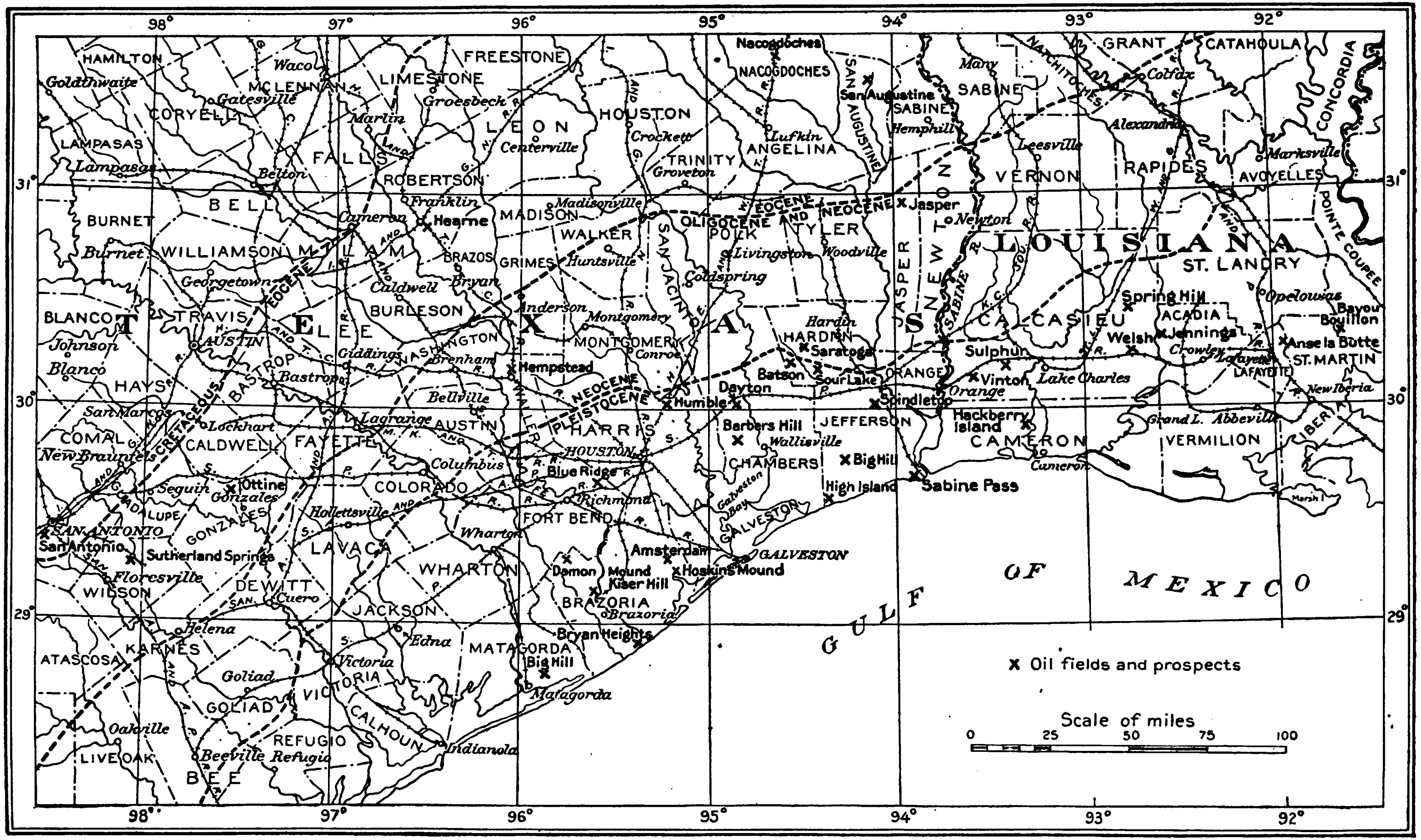

INDEX MAP SHOWING OIL FIELDS AND PROSPECTS.

OIL FIELDS OF THE TEXAS-LOUISIANA GULF COASTAL PLAIN.

By N. M. FENNEMAN.

INTRODUCTION.

The discovery of oil in the Gulf Coastal Plain created a demand for general geologic knowledge of that region and for specific knowledge of the geologic relations of the oil. This demand was for the time met by the publication, in 1903, of a report[a] by Messrs. C. W. Hayes and William Kennedy. The rapid development of the industry and the discovery of new pools, as well as the exhaustion of the edition of the former report, indicated the need of a new examination of the fields. The work whose results are reported in this bulletin was done between June 15 and September 15, 1904, and was directed chiefly to those phases of the subject on which new data were available. Accordingly, no stratigraphic work was attempted. Of the methods of drilling, the use of the oil as fuel, and (for the earlier-known pools) the physical and chemical properties of the oil there is little to be said now which was not well said by Hayes and Kennedy. It was not possible to visit all the localities where prospect wells have been sunk. Of many of these there is nothing to say except that nothing noteworthy was found. The number of such abandoned wells is so large that to ascertain merely the location and depth of each of them would have required much time and travel. In some cases it has been deemed advisable to publish the logs of such wells for comparison. In a few cases where the locality was examined and the results of drilling were learned by Mr. Kennedy and nothing has since been done, the statements made in the former report have been repeated in this. A large part of the work consisted in the collection of logs. A few are here published, having been selected on account of their representative character or because of special interest. Some were received in confidence. The remainder are preserved in the archives of the Survey and may be published later. In publishing logs the wording of the driller has been changed as little as possible.

ACKNOWLEDGMENTS.

To Messrs. Hayes and Kennedy, authors of the former report, the writer is under the greatest obligations. Where parts of that report have been used in this, the fact has been indicated by quotations or footnotes when practicable. Information and assistance in the field were received from a very large number of companies, managers, and drillers. Special acknowledgment and thanks are due to the following: President J. S. Cullinan and the officers of the Texas Company, for well reports of Spindletop, Sour Lake, Batson, and Saratoga, and for accurate maps from which Pls. V and VI and fig. 2 were made; to the officers of the Higgins Oil and Fuel Company; to President J. M. Guffey and General Supt. J. F. Fisher, of the J. M. Guffey Petroleum Company; to J. S. McNamara, of the United Oil and Refining Company; to E. Peperkorn, for maps; to W. E. Brice, Prof. F. C. Thiele, Underwood Nezro, George A. Hill, A. W. Hamill, Pattillo Higgins, W. H. Cunningham, and C. K. McFadden of Beaumont; to B. J. Harper, of Sour Lake; to Lee Hager,

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[a] Bull. U. S. Geol. Survey No. 212.

of the Rio Bravo (Southern Pacific Railroad) Oil Company; to H. B. Goodrich, of the Santa Fe Company, for special kindness in furnishing logs; to Dr. P. S. Griffith, for information concerning the Matagorda field; to J. A. Otto, of Ottine; to the Heywood Brothers, of Jennings; and to Robert Martin, of St. Martinsville, through whose kindness the visit to Bayou Bouillon was made possible. Important information was received from Mr. Holland S. Reavis, editor of the Oil Investors' Journal. For recent statistics and information of developments after the completion of the field work, the writer has relied chiefly upon the reports given by Mr. Reavis in his journal.

PREVIOUS KNOWLEDGE OF THE REGION.[a]

From Mississippi River westward through Louisiana and Texas, along the border of the Gulf of Mexico, is a low, flat country, partly swampy or marshy, as in the southern parishes of Louisiana, and partly a broad stretch of clayey and sandy land but slightly elevated above the level of these marshes. The marshy areas extend westward to the eastern shore of Galveston Bay, while the clayey areas may be said to extend as far west as Guadalupe River, in Victoria County, Tex. West of that stream, as far as the Rio Grande, the country is covered with sand and has a semiarid aspect. It may be added that this condition exists for many miles along the coast of the Mexican State of Tamaulipas. This region is known as the Gulf Coastal Plain.[b] It extends inland for a distance of from 50 to 100 miles. Forests of pine, oak, and magnolia fringe its northern border on the higher grounds, various species of gum occur on the lower benches, and heavy forests of black and red cypress occupy the low river flood plains, but the greater portion of the Coastal Plain is a treeless prairie.

These prairies have usually been designated the "coast prairies," and the beds which occupy the surface within the area are grouped under the general title of "coast clays." Comparatively little geologic work has been done in this prairie region, partly because the country was not considered of any economic value, and partly on account of the difficulties caused by the absence of anything like a natural section. The country is very flat, there are few streams flowing across it, and these few are flowing through broad, shallow channels filled with recent alluvium.

The only references made to these coast deposits in the published reports of the Texas State Geological Survey have been cursory and of a very general character. The most important is as follows:

"Immediately bordering the Gulf shore and forming the underlying slope we find a series of beds of clays, sandy clays, blue, yellow, red, and often mottled, which frequently appear black upon the surface from the combination of vegetable matter with the lime of the calcareous nodules which are found scattered through them. These clays are heavy, massive, containing small crystals of gypsum in places, and so compact that bluffs from 15 to 20 feet in height are often found along the streams and bay shores even in such a moist climate as that of Texas.

"The various strata which form these beds dip so slightly to the southeast as to appear nearly horizontal, and form the basis of the level coast prairies which stretch inland from the Gulf for distances varying from 50 to 100 miles.

"While the underlying beds of clay are seemingly identical for the entire Gulf coast, the overlying soil is somewhat different, being more sandy on the eastern and western borders and more clayey between Brazos and Nueces rivers."[c]

McGee regarded these deposits as belonging in part to his Lafayette formation and in part to his Columbia. He considers the region to have been built up for the most part from long wave-built keys separated from the mainland by sounds, although he says that "east of Galveston the keys and sounds appear to fail; yet the wave-built barriers are continuous as in southern Texas and eastern Mexico, though submerged beneath the Gulf waters to form Sabine Bank, Trinity Shoals, and Ship Shoal, and their connecting series of bars parallel with the coast."[d]

R. T. Hill describes these plains as a belt of prairie land not over 100 miles wide bordering the Gulf of Mexico in Louisiana and Texas. He regards it as a grass-covered constructional plain newly reclaimed from the Gulf of Mexico. The interior margin of this plain rises scarcely 100 feet above the sea, and it is characterized by an exceedingly level surface hardly broken except by a few low drainage grooves, which become fewer and more faintly developed toward the Rio Grande. Upon this plain a youthful drainage system is being established, while the seaward extensions of the through-flowing streams cross it. These rivers have wide and deeply indented valleys with gently terraced slopes filled with old alluvium.

"The floor of the sea border of Texas is a submerged gently sloping sandy plain, or shelf, extending 50 miles seaward. By action of tide, wave, current, and wind this sand is piled into long island strips which fringe the coast and stand almost at sea level. These are separated from the land by shallow lagoons, in which most of the sediments of the river are deposited. The building up of the sand bars by wind and wave and the filling up of the lagoons between them by river sediments, in connection with gradual uplift, may possibly explain the origin of much of the adjacent coast prairie."[a]

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[a] Reprinted with slight revision from Bull. U. S. Geol. Survey No. 212.

[b] This is the popular use of the term "Coastal Plain." Among geologists the term is applied to a broader belt, including the whole of the Louisiana and East Texas Timber Belt. As thus defined the Coastal Plain includes much hilly ground. See Hill, R. T., Physical geography of the Texas region: Topographic Atlas U. S. Geol. Survey, folio 3.

[c] First Ann. Rept. Geol. Survey Texas, 1889, p. xxxii.

[d] Twelfth Ann. Rept. U. S. Geol. Survey, 1892, p. 316.

Sufficient work has not been done in southwestern Louisiana to give us any clue to the structure of that portion of the Coastal Plain.

According to Hilgard, this portion of the coast country is built up partly of littoral and estuarine deposits and partly of swampy lagoon and fluviatile deposits, whose thickness and location are manifestly dependent upon the topographic features of the continent at the time they were laid down. The land at that time was being slowly depressed, as is shown by the nature of the deposits and by the numerous superimposed generations of large cypress stumps embedded in laminated clays, which exhibit the yearly fall of leaves. This view was also held by Hopkins in his survey of southwestern Louisiana in 1870-71.

The above theories regarding the upbuilding of the Coastal Plain may possibly apply to the newest extension in the east, along the Gulf of Mexico, which at present is altogether marshy, or to the comparatively arid region west of Nueces River, where at present we find a chain of such keys with their accompanying lagoons. The largest of these lagoons—Laguna de la Madre—is being rapidly filled up by the drifting sands from the higher dunes of Padre Island.

A study of the submerged portion of the Coastal Plain, as shown by the Coast Survey charts, shows that the general slope of the sea floor, as far out at least as the 5-fathom, or 30-foot, line, is not more than 5 to 7 feet per mile, and that there does not appear to be any uniformity in the deposition of the materials forming this floor. Lens-shaped deposits of hard blue clay and soft mud occur, irregularly interspersed with banks of fine and coarse gray sand and broken shells. The Sabine Bank is reported as being made up of a gray sand, with black specks and broken shells, which closely resemble much of the gray sand obtained from the different wells in the southeastern portion of the oil fields, especially in the neighborhood of Beaumont. It is probable that the upbuilding of the Coastal Plain, at least throughout about 500 feet of its upper portion, was carried on in the same manner as at present. Under the present Gulf the sands appear to be the heaviest deposits, and the well records at many places show the same conditions to exist down to a depth of 500 feet.

The existence of petroleum in this portion of the country has been known for many years. In 1860 Wall, quoting from Taylor's Statistics of Coal, mentioned the existence within 100 miles of Houston of a small lake filled with bitumen or asphaltum, and having in its center a spring from which during the summer months an oily liquid (probably petroleum) continually boiled up from the bottom.[b]

In 1880 S. F. Peckham quotes N. A. Taylor as to the existence of maltha in Texas, and gives Sour Lake as one of the localities. On the map accompanying his report oil-producing localities are marked as follows: At the mouth of the Brazos (near Bryan Heights, where considerable drilling has since been done); close to Port Arthur, in Jefferson County; in Newton and Orange counties, Tex.; and at several points in Calcasieu Parish, La.[c]

When the present oil development began, it was considered advisable to undertake the study of the Coastal Plain in order to bring together such geologic information as was available concerning the geologic relations of the various deposits and to assist in the economic exploitation of the oil fields.

[With this object in view the Gulf Coastal Plain was thoroughly studied by Mr. William Kennedy in the years 1901 and 1902. The various deposits of sands, clays, and sandstones were examined and compared, their continuity across the country was traced, and their geologic conditions and position in the general section of the region were studied. Mr. Kennedy's inferences were, so far as possible, drawn from observations on the small bluffs and cuttings seen along the courses of the rivers and creeks, as well as on such cuttings as could be found along the various railroads traversing the country. In addition the logs of the various deep wells throughout the whole Coastal Plain, so far as obtainable, were gathered, and the results of the borings collated and compared. The results of his study are published in Bulletin No. 212.[d] In the work which forms the basis of the present bulletin much attention was given to well sections and but little to natural exposures.]

By these means the general underground conditions of the region to a depth of about 2,000 feet have been determined and have been described so as to be readily understood by those immediately interested in the development of the field. There are, however, many questions regarding the underground structure that can not be answered until much more drilling has been done.

TOPOGRAPHY OF THE GULF COASTAL PLAIN.[e]

That portion of the Gulf Coastal Plain under discussion may briefly be described as a belt of country having a width of from 50 to 100 miles, extending around the shores of the Gulf of Mexico and embracing in Louisiana, in whole or in part, the parishes of Vermilion, Lafayette, Acadia, Cameron, Calcasieu, and Vernon; and in Texas the counties of Orange, Newton, Jefferson, Hardin, Jasper, Chambers, Liberty, Harris, Galveston, Brazoria, Matagorda, Fort Bend, Wharton, and portions of Waller, Montgomery, San Jacinto, Polk, and Tyler.

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[a] Physical Geography of Texas: Topographic Atlas U. S. Geol. Survey, folio 3.

[b] Geology of Trinidad, App. G, p. 136; Taylor's Statistics of Coal, p. 223.

[c] Tenth Census, Vol. X, p. 20, and map, Washington, 1884.

[d] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey No. 212, 1903.

[e] Revised and reprinted from Bull. U. S. Geol. Survey No. 212.

RELIEF.

The surface features of the Gulf Coastal Plain are extremely simple. In the immediate vicinity of the coast and for 15 or 20 miles inland, in the parishes of Vermilion and Cameron and in the counties of Orange, Jefferson, Chambers, and Galveston, the general level is scarcely more than 3 or 4 feet above the average tides of the Gulf. At a few points, such as Grand Chenier and Hackberry Island, in Cameron Parish, La., and Big Hill and High Island, in Jefferson and Galveston counties, Tex., there are pronounced elevations, of a few hundred acres in extent, rising to heights of from 40 to 50 feet above the level of the coast marshes. [These are called "islands," mounds, or hills. In the following pages all elevations of this class, whether in the coastal marshes or on the flat prairie farther inland, are termed mounds.]

Bordering the marsh along its northern edge is a second belt, largely prairie land, whose surface rises gradually toward the northwest, at an average rate of from 10 inches to a foot per mile.

A few small prominences appear within this belt, as at Spindletop and Fairchild Hill, in Jefferson County; at Sour Lake, Dayton, Barber Hill, Kiser Mound near Columbia, and Damon Mound in Brazoria County; and the Sun Mounds, in Waller County. These, however, do not present any great elevations, Damon Mound, probably the highest, having a maximum of 83 feet above the plain, or probably not more than 140 feet above the Gulf.

[Aside from the elevations commonly called mounds, there is on the uneroded parts of the Coastal Plain another typical topographic feature, usually spoken of as "gas mounds." The name is objectionable because their origin is in doubt. Their presence makes the so-called "pimpled plains." They are circular lumps, generally 1 or 2 rods in diameter and ranging in height up to 5 or 6 feet. They are scattered over thousands of square miles and, considering their vast number, their approximate uniformity in shape and size is noteworthy.]

The third or inner belt of country belonging to the Coastal Plain rises comparatively rapidly from the second and has a more broken and generally timbered surface, with numerous small rounded hills. The general elevation of this belt does not appear to exceed 175 to 200 feet above sea level.

DRAINAGE.

In the eastern part of the region throughout Louisiana the rivers are deep and sluggish. The few streams of any magnitude are the Bayou Vermilion, Bayou Mermentau, and Calcasieu River. Each of these streams is narrow, deep, and clear, has scarcely any appreciable current, tends to expand into a broad, shallow lake, and enters the Gulf through a shallow bay. Bayou Vermilion flows into Vermilion Bay. The Mermentau shortly after the junction of Bayous Nezpique and Des Cannes expands into the broad, shallow Grand Lake, with a depth of little over 3 feet, and again contracts only to enter the Gulf through a wide mouth. The Calcasieu forms a series of shallow lakes such as Calcasieu, Black, and West lakes, extending all the way from Lake Charles to the coast. These Louisiana rivers all have the peculiar characteristics of drowned or submerged streams.

Throughout the Coastal Plain in southeast Texas the streams are similar in character to those in Louisiana. The Sabine and Neches unite to form Sabine Lake; the Trinity debouches into the eastern end of Galveston Bay; the Colorado reaches the Gulf through Matagorda Bay, and the Nueces flows into Corpus Christi Bay. Of all the rivers in this area the Brazos alone enters the Gulf directly and without the intervention of any lagoon or bay.

West of the Nueces the coast drainage fails almost absolutely, as the whole stretch of coast line to the Rio Grande contains only two small creeks, the San Fernando and the Olmos, and these unite to form Copano Bay, near the head of Laguna de la Madre.

These streams of the Gulf Coastal Plain may be divided into two groups—an older, pre-Pleistocene or pre-Columbia, and a younger, post-Columbia. The pre-Columbia (and probably even pre-Lafayette) group includes the Sabine, Neches, Trinity, Brazos, Colorado, Guadalupe, and Nueces, all of which appear to have been in existence during Lafayette time. The younger, or post-Columbia, rivers are the Vermilion, Mermentau, Calcasieu, San Jacinto, Buffalo, Clear, Oyster, San Bernard, Caney, Lavaca, Aransas, San Fernando, and Olmos.

A glance at the map of the region[a] will show the reasons for this division. It will be noticed that all the rivers included in the older group pass completely across the Coastal Plain, heading upon the older formations of the interior, while the streams of the second or younger class are confined wholly to the plain itself, heading within it, or in the strong springs which rise from the Fayette sands at its northern border.

Notwithstanding the large number of rivers which occur in the Coastal Plain, much of its surface is poorly drained. Water stands in many small lakes or ponds throughout the year, and over considerable areas the surface is largely under water during the wet season.

TIMBER.

Regarding the timber of the Coastal Plain it may be broadly stated that the cypress is confined to the eastern end, or to the swamps occurring within the immediate drainage area of the Mississippi River, very few of these trees occurring west of the Sabine River. The magnolia (*M. grandiflora*) is found in a belt stretching in a general southwestern direction through the parishes of Sabine and Vernon, La., and the counties of Newton, Jasper, Hardin, Liberty, and San Jacinto, Tex., terminating in a few straggling trees in the neighborhood of Houston. The western end of the great southern belt of pine is reached near the Brazos River. West of the Brazos the tree growth is mostly represented by oaks and mesquite, the latter gradually becoming the only timber to be found.

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[a] Bull. U. S. Geol. Survey No. 212, Pl. I.

GEOLOGY OF THE GULF COASTAL PLAIN.

DESCRIPTION OF SEDIMENTS.

As indicated above under the heading "Previous knowledge of the region," the sediments of the Coastal Plain consist of generally unconsolidated clays, sands, and marls. The beds lie in essentially the same position in which they were deposited. Their seaward dip is a little greater than the seaward slope of the surface, causing younger beds to come to the surface nearer the coast.

The first of the sediments to become consolidated are the marls. Beds of limestone from a few inches to a few feet in thickness are of common occurrence. It is repeatedly noted that the consolidation of the calcareous beds bears a distinct relation to their thickness, the consolidated beds being generally thin (see pp. 25, 98). Sands cemented by carbonate of lime are found, sometimes as sandstone beds and sometimes as concretions or "bowlders." No consolidated beds of clay are known, but some of the clays contain concretions. In addition to the consolidated sedimentary beds, there are certain solid materials of secondary origin, described on page 16. The most important of these is the crystalline and cavernous limestone from which a large part of the oil has been derived.

STRATIGRAPHY.

DIFFICULTY OF CORRELATION.

These deposits have not yet been sufficiently studied to make possible an entirely satisfactory or final classification. Correlations between widely separated exposures are often only tentative. There are three reasons for this imperfection of the present knowledge: (1) The almost complete lack of natural exposures; (2) the want of sufficient evidence from fossils, due largely to the scarcity of exposures; (3) the lack of lateral continuity in the physical character of the beds and the corresponding variation in vertical section in beds of the same age.

By a comparison of a large number of well sections from one locality, it is generally possible to subdivide the formations into broad but indefinite zones, each characterized by the dominance of a certain kind of sediment (see pp. 58, 99). Such zones may be a few hundred feet in thickness. Within these zones each well section shows numerous well-defined beds, the characters of adjacent beds often being sharply contrasted; but when sections of neighboring wells are compared it is found that beds of like character and thickness do not occur at similar depths in the several well sections. Generally it is quite impossible to identify the individual beds passed through in one well with those passed through in another (see fig. 3, p. 61). Attempts to do this have led to grotesque assumptions of folds and faults.

FOSSILS.

A few fossils have been obtained from borings, but these fix the age of the sediments only within very broad limits. The best-known section whose fossils have been studied is that of the Galveston well. According to Harris,[a] the deposits appear to be as follows:

Section of Galveston well.

	Feet.
Pleistocene	46- 458
Doubtful	458-1,510
Upper Tertiary	1,510-2,158
Miocene (upper)	2,158-2,720

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[a] Fourth Ann. Rept. Geol. Survey Texas, 1893, pp. 89 et seq.

In harmony with this generalization is a small amount of evidence from fossils taken from wells in or near the Spindletop field. Hayes and Kennedy give the following section:[a]

Section constructed chiefly by means of fossils obtained from wells in the Beaumont district.

	Location.	Character of strata.	Depth in feet.	Fossils.	Age.
1	Louisiana	Clay, yellow and blue	40	Ostrea sp.	
2	Harby well	Clays and sands, blue and yellow.	45	Rangia cuneata (Gray).	Post-Pliocene.
3	Spindletop	Blue clays with coarse bluish-gray sand and shells.	390	Nassa beaumontensis Aldrich. Tornatina canaliculata Say. Turbonilla sp Mactra sp	Pliocene.
4	Island well, on Neches River.	Blue clay	800	Natica tuomeyi Whitfield. Crassinella like galvestonensis. Corbula.	Miocene.
5	Ira O. Wyse well, Spindletop.	Bluish-gray coarse sand and shells.	1,000	Mulinia, Balanus	Miocene.
6	Plunger well, Texas Oil and Pipe Line well No. 1, Spindletop.	Dolomitic marls with gypsum; oil rock shown in every well on Spindletop.	1,036	Ostrea virginica	Miocene.
7	Bayou City well, on Iowa Colony land.	Coarse bluish-gray sand with shells same as found in Ira O. Wyse well at 1,000 feet	1,910	Mulinia, Balanus Ear bone of small fish	Miocene.
8	Frio clays, Newton County.	Blue clay with calcareous nodules.		Crassatellites trapaquara Harris. Ostrea alabamiensis; Cerithium venericardia, 2 sp. Crassatellites antestriata (Gabb).	Eocene.

A number of fossils from a depth of 323 to 333 feet at Batson (Gilbert well No. 10) are pronounced by Dall identical with those of the Galveston well and probably uppermost Miocene. The fossils are:

Olivella mutica Say.
Nassa acuta Say.
Utriculus canaliculatus Say.
Pecten, fragm.
Arca transversa Say, young.
Arca (Adamsi? Smith), fragm.

Solen, fragm.
Dosinia (very young).
Mulinia lateralis Say, young.
Corbula galvestonensis Harris.
Balanus, fragm.
Bryozoan, fragm.

A sample from a depth of 649 to 668 feet in a well at Bryan Heights, near Velasco, contained organic remains which are not older than upper Miocene. Three fossils from the Magenta well at Montegut, Terrebonne Parish, La., were taken from depths between 1,386 and 1,767 feet. They indicate that the beds at that depth are the upper Miocene shell sand, represented by the lower 1,500 feet of the well at Galveston.[b]

It may be safely inferred that the same stratigraphic horizon which is 323 feet below the surface at Batson is between 400 and 800 feet deep at Spindletop and from 1,500 to 2,000 feet deep at Galveston. This implies dips of from 10 to 20 feet per mile.

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[a] Bull. U. S. Geol. Survey No. 212, 1903, p. 25. The determinations of the Miocene fossils were by Dr. W. H. Dall.

[b] The determinations of the fossils from Batson, Bryan Heights, and Montegut are by Doctor Dall.

KENNEDY'S GENERAL SECTION.

While no system of classification and correlation of the systems of the Texas Coastal Plain is universally agreed on and any such system may be altered by fuller data in the future, Mr. Kennedy's section, given below, is valuable as a description of the formations. His geologic map[a] is based upon the stratigraphic classification here given. The geologic boundaries given on Pl. I are taken from a map published by Mr. Lee Hager, by whom they were compiled from various sources. For reasons given under the heading "Geologic relations of the oil" (p. 117), a knowledge of the general physical character of the entire mass of sediments is belived to be more important in the study of the oil than are the details of stratigraphy.

General section of eastern division of Texas-Louisiana Gulf Coastal Plain.

	Thickness in feet.
1. Recent: Coastal marshes, consisting chiefly of sea flats subject to overflow at extremely high tides, swamps, and partly submerged lands, and the bottom lands along the rivers. The life is represented by recent shells, such as *Rangia cuneata* and *Ostrea*. Beds of these shells occur along the rivers, and at many of the smaller lakes in this region	5 to 25
2. Pleistocene, with probably some Pliocene:	
a. Beaumont clays: Brown, blue, and yellow clays, carrying nodules of limestone in places irregularly distributed through the clays, making the soil black where found; brown and blue sands with great quantities of cypress wood and recent shells	25 to 400
b. Columbia sands: White, yellow, gray, and mottled sands with beds of blue and yellow clay, some decayed wood, and a heavy deposit of gravel at base. In the clays belonging to these beds at Sour Lake such vertebrates as *Mammut, Megalonyx, Equus, Smilodon fatalis*, etc., have been found[b]	50 to 200
3. Neocene (Miocene, with probably some Pliocene):	
a. Lafayette sands: Blue and red thinly laminated clays; massive red and brown clays; and red and brown cross-bedded sands and gravels carrying pinkish inclusions of clay	30 to 375
b. Blue, brown, and gray clays; sands with thin beds of limestone and containing small quantities of oil	300 to 480
c. Blue clays and thin-bedded irregularly deposited sandstones	200
d. Blue, red, and gray clays and sands and thin-bedded limestones; limestones dolomitized and associated with sulphur, gypsum, gas, and petroleum. Sands carry fossils of Miocene age	300
4. Eocene:	
a. Frio clays: Blue, brown, red, yellow, and green clays, thinly laminated, partially stratified and massive. The laminated clays carry small crystals of gypsum, and the massive clays numerous concretions of lime from 2 to 4 inches in diameter and calcareous-ferruginous concretions from 6 inches to 2 or more feet in length. Fossiliferous in places and changing to sandy calcareous clays to the west	260
b. Fayette sands: Gray sands and gray and white sandstones interstratified with gray, white, and pink clays and sandy clays. The lower sandstones are often hard and glassy, and bluish or pinkish in color. The upper sandstones are soft and chalky white, and contain numerous casts of grass, reeds, palmetto, and other marsh plants. At some localities a thin bed of limestone in these upper sandstones carries	

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[a] Bull. U. S. Geol. Survey No. 212, Pl. I.

[b] Leidy, Joseph, Contributions to the extinct vertebrate fauna of the western Territories: Mon. U. S. Geol. and Geog. Surv. Terr., vol. 1, 1873.

	Thickness in feet.
lower Claiborne fossils, and a yellowish-brown sand contains a considerable number of plant impressions	400
c. Yegua clays: Dark-blue gypseous clays and dark bluish-gray sands with considerable deposits of lignite	1,000
d. Upper marine beds or Cooks Mountain beds: A series of greensands, fossiliferous greensands, fossiliferous clays, stratified black and gray sandy clays, black and yellow clays with limy concretions. A very prolific Claiborne fauna	390
e. Mount Selman beds: Brown sands, blue clays, greensands, glauconitic sandstone, and heavy deposits of limonite. More or less fossiliferous, but fauna mostly represented by casts	260
f. Lignitic: White, yellow, gray-brown, red, blue, and black sands with interstratified and interlaminated blue, gray, and brown clays with heavy beds of lignite. Apparently unfossiliferous except for a few plant remains, including the palmetto	1,060
g. Wills Point clays: Yellowish-brown sands containing bowlders of sandstone and limestone with some calcite concretions; dark-blue and brown laminated and massive clays and fossiliferous white limestone	260
5. Cretaceous.	

THE MOUNDS.

FORMATIONS.

Beneath the mounds (p. 12) are various materials which, in general, are not found elsewhere on the Coastal Plain. These materials—crystalline limestone, sulphur, gypsum, and rock salt—are generally covered by the unconsolidated sediments described above. In some cases this covering is very thin, as at Damon Mound, where the limestone outcrops, and at Avery Island, Louisiana, where the rock salt was found at one place within 15 feet of the surface. At Spindletop the limestone is 800 to 900 feet deep, and at Hackberry Island, Louisiana, a similar rock was found more than 1,600 feet deep.

The limestone is frequently dolomitic and at places entirely crystalline. When stained by oil it resembles maple sugar. At some places it is dense. Both the dense and the crystalline varieties may be cavernous. Some limestone bodies are more than 100 feet thick. It can not be doubted that the pure calcite which forms large parts of the porous oil-bearing limestone is deposited from solution in water. Some large masses may thus have been formed by material brought long distances. In most cases observed, however, there is an abundant source of carbonate of lime in the highly calcareous sediments immediately adjacent to or below the secondary limestone. Some of these calcareous beds are in the original condition of marl, others consolidated without the formation of crystalline calcite. Still others are partly composed of redeposited material, so that between the original marl bed and the entirely secondary limestone there are all possible gradations. The nature of this porous limestone is further discussed in the descriptions of the several fields (see pp. 26, 45, 52).

At about the horizon of the limestone and sometimes contained within its caverns (see table below, p. 17) sulphur is frequently found. In many cases it is almost chemically pure. Well-formed crystals more than an inch long have been obtained. Probably these are generally from cavities in the limestone. Some of such cavities which have been filled with oil are lined with minute sulphur crystals. Sands at higher horizons occasionally contain a large admixture of sulphur.

Gypsum occurs both as a massive rock and as an admixture in sands and clays. It generally lies deeper than the limestone and the sulphur (see table below).

Salt is abundant. In the salt islands of Louisiana it is very pure. That which has been found below the limestone of the oil fields is likewise believed to be pure rock salt. Salt no doubt also impregnates some sands, especially on the borders of the large masses of rock salt.

RELATIVE POSITIONS OF FORMATIONS.

The relative positions of these substances which characterize the mounds are given in the following tables:

Occurrence of characteristic materials in Coastal Plain mounds.

POROUS (FREQUENTLY DOLOMITIC) LIMESTONE.

Spindletop	Between sediments above and sediments (often marly) below. Two horizons of limestone at many places.
Sour Lake	Between sediments above and marl or sand below.
Batson	Between sediments above and sand or "soapstone" below.
Matagorda	Between various sediments above and marl below.
Damon Mound	Outcrops at places; at others covered by sediments.
Bryan Heights	Overlain by sediments, but lies above gypsum and sulphur.
Kiser Hill	In bodies of unknown form, inclosed by sediments.
Dayton Hill	Limestone, probably of the character here referred to, occurs between sediments above and gypsum below.
Big Hill (Jefferson County)	Between sediments above and gypsum below.
Hackberry Island	Overlain by sediments; underlain by sand and gypsum.
Sulphur Mine	Between sediments above and a mixture of limestone and sulphur below.

SULPHUR.

Spindletop	In, above, and below the oil-bearing limestone, probably generally in caverns of limestone, but at places mixed with sediments above the porous limestone.
Batson	In porous limestone (?).
Matagorda	Abundant, probably in caverns of limestone; some in marl below limestone; some in sediments near horizon of the oil.
Damon Mound	Mixed with gypsum and overlain by pure gypsum; at other places mixed with loose sediments.
Bryan Heights	In gypsum, below the small showings of oil.
Big Hill (Jefferson County)	"Seams" in gypsum underlying dolomitic limestone.
Vinton Mound	Mixed with sediments; probably associated with gypsum at greater depths; crystals in cavities of limestone (?).
Sulphur Mine	In cavities of limestone; overlain by solid limestone.

GYPSUM.

Spindletop	Between porous limestone above and salt below.
Sour Lake	Below oil-bearing limestone (?).
High Island	Between sediments above and salt below; also cementing some sediments.
Damon Mound	Overlain by loose sediments; underlain by "sulphur and gypsum," beneath which is coarse sand.
Bryan Heights	Below loose sediments and crystalline limestone.
Barbers Hill	Mixed with sand or occurring as concretions at various depths.
Dayton Hill	Between limestone above and salt below.
Big Hill (Jefferson County)	Beneath dolomitic limestone; possibly also streaks (?) in the limestone.
Vinton Mound	Beneath sediments; may be solid or mixed with sediments.
Hackberry Island	Separated by 10 feet of sand from crystalline limestone above.
Sulphur Mine	Unverified reports give a mixture of gypsum and sulphur beneath limestone and sulphur.

SALT.

Spindletop	Below gypsum; thickness not known.
Sour Lake	Below sand or marl which underlies porous limestone; thickness not known.
High Island	Below gypsum; not passed through by well 2,600 feet deep.
Damon Mound	Separated from gypsum above by 8 feet of sand; drilled in from 587 to 1,160 feet; not passed through.
Dayton Hill	Beneath gypsum; salt not drilled through at 1,300 feet.
Anse la Butte	Beneath sediments; drilled in from 220 to 1,603 feet without passing through; offshoots from central mass have sediments above and below.
Salt Islands	Beneath loose sediments; at least several thousand feet thick in some cases.

From the above tabulation the conclusion may be drawn that the normal order of depth of the materials in the mounds or oil fields is as follows:

4. Unconsolidated sediments.
3. Porous limestone.
2. Gypsum.
1. Salt.

While the position of sulphur varies, it is most frequently found in or near the limestone. Petroleum is associated with the porous limestone and the overlying sediments.

SPINDLETOP FIELD.

TOPOGRAPHY.

The low mound which, since the oil development there, has been known as Spindletop, is 3 miles southeast of Beaumont. It has a maximum elevation of 30 feet above the sea and 10 feet above the adjacent coastal prairie, which is entirely flat or of the type called "pimpled plains" (p. 12). The area of the mound is but little more than 200 acres. About one-half of this area is more than 7 feet above the prairie and is almost flat. The surface is unaffected by stream erosion. The peripheral slope is steepest on the south side and least observable on the north. There is a slight tendency toward elongation westward with a very gentle sag separating the westernmost portion from the main body of the mound.

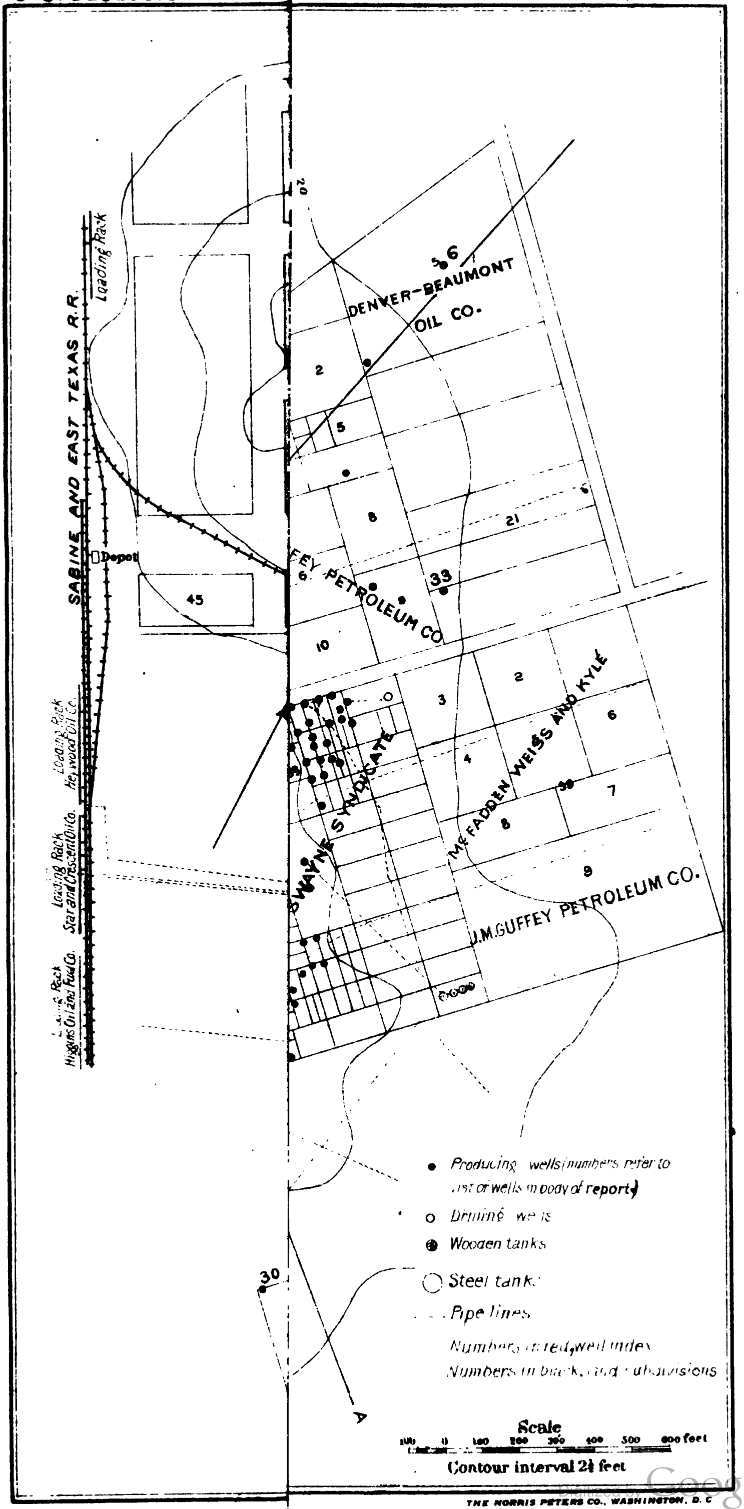
It is quite probable that the existence of the elevation is dependent on the geologic structure. If this assumption be correct, the mound is very significant with reference to the location of the oil field. The details of the surficial form have, however, no appreciable relation to geologic structure or to the exact distribution of oil. Some prospectors for oil have attached undue importance to minute analogies of surface slopes and have been guided by them in the location of wells on other mounds.

AREA.

The Spindletop oil field is, to a very striking degree, coextensive with the mound, though on certain sides the boundaries of the two areas are separated by a few hundred feet. The pool has of course been narrowed by the withdrawal of the oil and the encroachment of salt water. It is impossible to determine with exactness the original limits of the oil body, since these shift as soon as a part of the oil is withdrawn. Late in the history of a field, therefore, only salt water may be obtained from an area which, had it been drilled earlier, might have yielded oil.

SURFACE INDICATIONS AND FIRST DRILLING.

For many years certain surface indications directed attention to this slightly elevated spot as a possible oil field. The most evident of these phenomena was an escape of gas, noticed in pools after a rain, as well as in some shallow water wells. At least a part of this


SABINE AND EAST TEXAS R.R.
Loading Rack
Depot
Loading Rack Heywood Oil Co.
Loading Rack Star and Crescent Oil Co.
Loading Rack Higgins Oil and Fuel Co.
DENVER-BEAUMONT OIL CO.
FEY PETROLEUM CO.
SWAYNE SYNDICATE
McFADDEN WEISS AND KYLE
J.M.GUFFEY PETROLEUM CO.
20
30
33
45
21
A
Producing wells (numbers refer to list of wells in body of report)
Drilling wells
Wooden tanks
Steel tanks
Pipe lines
Numbers in red, well index
Numbers in black, land subdivisions
Scale
100 0 100 200 300 400 500 600 feet
Contour interval 2½ feet

THE NORRIS PETERS CO., WASHINGTON, D. C.

gas appears to have been sulphureted hydrogen. Incrustations of sulphur were observed in the soil and considerable importance is said to have been attached to these by Captain Lucas, under whose management the first successful oil well was completed on January 19, 1901.[a] The slightly sulphurous waters found in certain shallow wells were regarded as significant for the same reason. "Sour waters" (see p. 124) are also said to have been noted at Spindletop, but they are not now much in evidence. The composition of the escaping gases, aside from sulphureted hydrogen, has not been definitely determined. Hill also mentions Spindletop among the localities where seepages of oil were observed at the surface. One of the most potent reasons for drilling here seems to have been the suggestiveness of the topographic form. Captain Lucas had become convinced, from his work in Louisiana, that salt, sulphur, gypsum, dolomite, sulphureted hydrogen, and oil were in some way associated with such mounds or "islands."[b]

It is not so well known just what phenomena were influential in leading to earlier drillings than that of Captain Lucas. It is but fair, however, to record that Mr. Pattillo Higgins, for some years previous to the actual discovery, insisted constantly and confidently on the presence of petroleum under Spindletop, and it was he who, several years before the finding of oil, laid out Gladys City in anticipation of the coming importance of that locality. In 1894 a well was drilled to a depth of 400 feet. It was too shallow to reach the oil, but it afforded certain slight indications which gave encouragement to the later successful attempt.

WELL SECTIONS.

As the geology of Spindletop can be known only from data obtained in drilling, a few typical logs are given here.[c] They illustrate most of the features of the formations to be discussed, and at the same time show the great differences among well sections.

Logs of wells in Spindletop field.

HIGGINS WELL NO. 2.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Soil, black sandy loam	⅔	⅔
2	Yellow clay with red streaks	3⅓	4
3	Blue clay with limy concretions	12	16
4	Bluish-gray sand	6	22
5	Yellowish-colored clay with lime	8	30
6	Dark-blue clay with some lime and shells	10	40
7	Gray sand	16	56
8	Blue sand	13	69
9	Blue clay with pyrites	51	120
10	Blue sand with some clay and small pebbles	26	146
11	Fine bluish-gray sand	10	156
12	Fine gray sand	31	187
13	Fine gray sand with black specks	10	197
14	Bluish-tinted gray sand	65	262
15	Dark-gray sand with black specks	9	271
16	Fine dark-gray sand	44	315
17	Fine grayish-tinted sand	35	350
18	Fine grayish-green sand	50	400
19	Fine brownish-gray sand	40	440
20	Fine brown sand with shells	30	470
21	Fine brown sand with broken shells	21	491
22	Coarse blue sand with broken shells	9	500

[a] See Hill, R. T., Trans. Am. Inst. Min. Eng. 1902, pp. 31, 35.

[b] Hill, R. T., loc. cit., p. 34.

[c] Additional logs are published in Bull. Univ. Texas Mineral Survey No. 1 and in Bull. U. S. Geol. Survey No. 212.

Logs of wells in Spindletop field—Continued.

HIGGINS WELL NO. 2—Continued.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
23	Very fine muddy sand	47	547
24	Very fine bluish-gray sand	17	564
25	Very fine gray sand with bluish tint	48	612
26	Fine gray sand with bluish tint	12	624
27	Fine sandy clay (fish bones at 628 feet)	42	666
28	Fine blue sandy clay	6	672
29	Very fine light-blue sand	13	685
30	Light-blue rock	43	728
31	Bluish-gray sand	8	736
32	Light-gray sand with shells	14	750
33	Marl with small shells	6	756
34	Light bluish-gray sand and shells	5	761
35	Fine sand and shells	64	825
36	Very fine dark brownish-gray sand	49	874
37	Hard grayish-blue sandy clay, with shells and heavy indications of oil	26	900
38	Dark rock 2 feet, shells 1 foot	3	903
39	Dark grayish-blue sand with some clay	12	915
40	Lignite	5	920
41	Bluish-gray sand with shells	34	954
42	Bluish-gray rock	4	958
43	Very fine grayish-brown sand with shells	24	982
44	Very fine sand with shells	13	995
45	Dark gray rock, "cap rock"	5	1,000
46	Coarse dark-gray sand with oil	6	1,006

HIGGINS WELL NO. 3.

1	Soil and clay	17	17
2	Sand	6	23
3	Clay	20	43
4	Quicksand with clay	40	83
5	Water sand	15	98
6	Blue marl	80	178
7	Quicksand	130	308
8	Blue clay	10	318
9	Water sand	35	353
10	Blue marl	30	383
11	Quicksand	42	425
12	Rock	1	426
13	Quicksand	44	467
14	Sand rock	4	471
15	Blue marl	50	521
16	Shell rock	3	524
17	Blue marl	60	584
18	Quicksand	30	614
19	Rock	6	620
20	Blue clay	3	623
21	Rock	2	625
22	Blue clay	7	632
23	Rock	4	636
24	Blue marl with sand	30	666
25	Rock	1	667

Logs of wells in Spindletop field—Continued.

HIGGINS WELL NO. 3—Continued.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
26	Blue sand	80	747
27	Blue clay	12	759
28	Shell rock	14	773
29	Blue marl	60	833
30	Rock	5	838
31	Blue clay	10	848
32	Rock	6	854
33	Blue clay	12	866
34	Oil sand	20	886
35	White lime rock	103	989
36	Sulphur and oil sand	19	1,008
37	White lime rock	73	1,081
38	White lime rock with sand	225	1,306
39	Sand with a little gas	1	1,307
40	White lime with sand	173	1,480
41	Sand with very little gas	1	1,481
42	White lime with more sand than heretofore	46	1,527
43	Salt-water sand	40	1,567
44	White lime and sand rock	53	1,620
45	Same, with gas	5	1,625
46	Rock	22	1,647
47	Rock salt	309	1,956
	Quit in rock salt.		

HIGGINS WELL NO. 7.

1	Yellow and red clay	21	21
2	Very fine sand	8	29
3	Blue clay with some shells	56	85
4	Coarse sand and sulphur water	9	94
5	White clay with fine shells	20	114
6	Very coarse sand, much water	210	324
7	Red and gray clay, very sticky	10	334
8	Fine sand with shells and gravel	79	413
9	Gumbo, very sticky	63	476
10	Sand with showing of oil	4	480
11	Blue clay	25	505
12	Sand with rotten wood	1	506
13	Sand rock	2	508
14	Sticky clay, very dark	42	550
15	Cement rock, shells, and sand	2	552
16	Very fine loose sand	5	557
17	Very hard sandstone	1	558
18	White sticky clay very hard	7	565
19	Lime rock (cemented shells)	2	567
20	Clay, very gummy	8	575
21	Soft, white limestone	2	577
22	White clay	52	629
23	Very hard blue flint rock	1	630
24	Rock, shells, and clay	37	667
25	Hard sandstone	2	669
26	White clay, very gummy	35	704
27	Very hard white limestone	5	709

Logs of wells in Spindletop field—Continued.

HIGGINS WELL NO. 7—Continued.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
28	Sand with strong gas pressure	13	722
19	Sulphur and white rock mixed	24	746
30	Very porous oil rock	24	770
32	Very hard clay	2	772

This is one of the shallowest wells in the field which reached the oil-bearing limestone.

SOUTHERN COMPANY'S WELL NO. 4.

1	Soil	35	35
2	Quicksand	130	165
3	Shells	4	169
4	Water sand	186	355
5	Gravel	68	423
6	Sand and shells	79	502
7	Rock with pyrite	4	506
8	Gumbo	142	648
9	Sand with shells	24	672
10	Shells	48	720
11	Gumbo	64	784
12	Wet sand	39	823
13	Rock and gumbo	22	845
14	Sulphur	3	848
15	Flint rock (?)	3	851
16	Sand and shells	32	883
17	Gumbo	9	892
18	Sand rock	1	893
19	Gumbo	8	901
20	Flint rock (?)	4	905
21	Gumbo	60	965
22	Sand with shells	16	981
23	Sulphur	1	982
	Cap rock.		

DENVER-BEAUMONT OIL, TANK, AND PIPE LINE COMPANY'S WELL NO. 1.

1	Yellow clay	42	42
2	Quicksand	18	60
3	Yellow sand	22	82
4	Blue sand	21	103
5	Gumbo	42	145
6	Hard shale	1	146
7	Gumbo	84	230
8	Hard shale	22	252
9	Gumbo	44	296
10	Hard shale	76	372
11	Gumbo	44	416
12	Hard shale with shells	35	451
13	Heavy gumbo	45	496
14	Hard shale with shells	18	514
15	Sand rock with some oil	2	516
16	Hard shale with shells	81	597
17	Quicksand	10	607
18	Hard shale with shells	11	618

Logs of wells in Spindletop field—Continued.

DENVER-BEAUMONT OIL, TANK, AND PIPE LINE COMPANY'S WELL NO. 1—Continued.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
19	Hard lime rock with some shells	33	651
20	Quicksand	3	654
21	Crystallized limestone with sharp sand	27	681
22	Quicksand	12	693
23	Gumbo	14	707
24	Hard lime rock	1	708
25	Hard shale with shells	9	717
26	Soft shale	29	746
27	Hard lime rock	4	750
28	Gumbo	8	758
29	Crystallized lime rock	2	760
30	Gumbo	11	771
31	Hard lime rock	11	782
32	Gumbo	5	787
33	Lime rock with some oil in the seams	39	826
34	Gumbo	6	832
35	Hard lime rock	3	835
36	Gumbo	61	896
37	Hard shale	26	922
38	Gumbo	67	989
39	Hard lime rock	1	990
40	Gumbo	52	1,042
41	Hard shale with stratum of lime rock	11	1,053
42	Gumbo	42	1,095
43	First cap rock, oil sand, shells and some oil	½	1,095½
44	Hard shale with small limestone strata	1½	1,097
45	Second cap rock, like first, with considerable oil	1	1,098
46	Hard shale with crystallized lime rock	3	1,101
47	Third cap rock, like first	2	1,103
48	Oil sand	7	1,110

The following wells are specifically referred to in the discussion:

Spindletop wells referred to in the text.

[The numbers at the left correspond to those on the map, Pl. II, p. 18.]

1. Andrews No. 1.
2. Andrews No. 2.
3. Cartwright No. 1.
4. Cartwright No. 2.
5. Confederated No. 3.
6. Denver-Beaumont.
7. Gladys No. 1.
8. Gladys No. 3.
9. Gladys No. 4.
10. Gladys No. 6.
11. Gladys No. 8.
12. Gladys No. 18.
13. Hamilton-Prince.
14. Heywood No. 1.
15. Heywood No. 2.
16. Heywood No. 3.
17. Higgins No. 1.
18. Higgins No. 2.
19. Higgins No. 3.
20. Higgins No. 4.
21. Higgins No. 5.
22. Higgins No. 6.
23. Higgins No. 7.
24. Higgins No. 8.
25. Higgins No. 10.
26. Higgins No. 15.
27. Higgins No. 16.
28. Higgins No. 19.
29. Iowa-Beaumont.
30. Lone Acre.
31. McFaddin No. 1.
32. McFaddin No. 2.
33. McFaddin No. 5.
34. McFaddin No. 7.
35. McFaddin No. 13.
36. McFaddin No. 25.
37. McFaddin No. 4.
38. National Oil and Pipe Line Co. No. 1.
39. National Oil and Pipe Line Co. No. 2.
40. National Oil and Pipe Line Co. No. 3.
41. National Oil and Pipe Line Co. No. 7.
42. Southern No. 4.

SEDIMENTARY FORMATIONS ABOVE THE OIL.

Above the horizon of the oil are 700 to 1,000 feet of generally unconsolidated sediments. They are not distinguishable from the beds under the adjacent prairie. Named in the order of their abundance, these beds consist of clays, sands (with gravels), and limestones (with shell beds). In general, individual beds can not be traced from well to well, except for very short distances. A stratum of from 15 to 25 feet of clay at the top is general.

SANDS.

The first 500 feet generally have a predominance of sand. From that depth down to the oil rock, sands are generally very subordinate in amount when not entirely absent. The logs of a considerable number of wells which are well distributed over the field show the following proportions of sands in their upper portions:

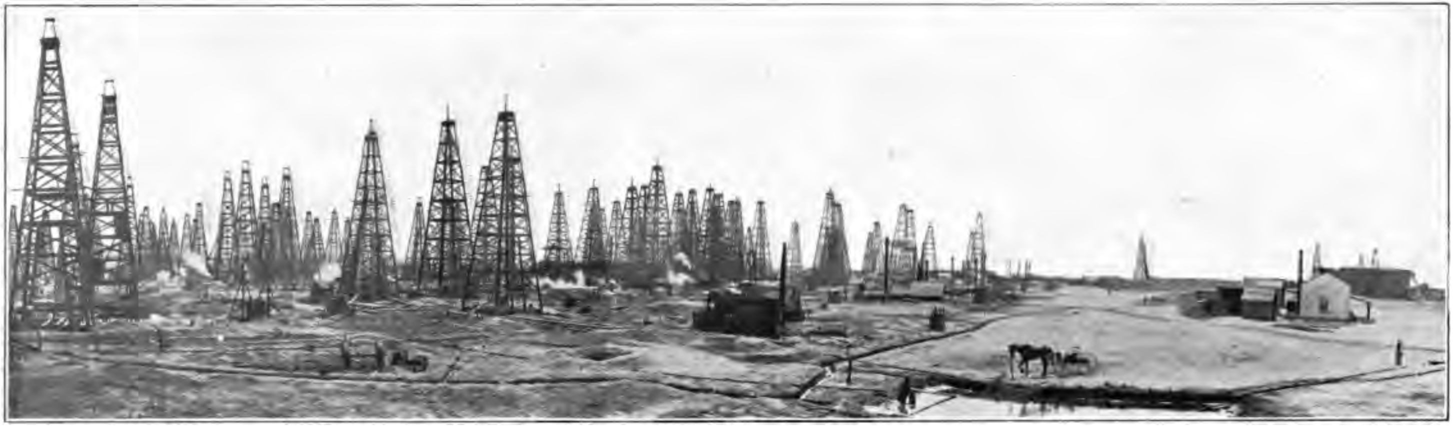
Proportions of sand in Spindletop well sections.

Well.	Thickness of sand or gravel.	Out of first—	Well.	Thickness of sand or gravel.	Out of first—
	Feet.	*Feet.*		*Feet.*	*Feet.*
Higgins No. 3	316	471	Higgins No. 16	395	590
Higgins No. 4	180	350	Higgins No. 19	438	512
Higgins No. 5	296	544	Lucas	356	598
Higgins No. 6	404	560	Southern No. 4	373	502
Higgins No. 7	305	413	Heywood No 2	419	595
Higgins No. 8	340	510	Heywood No. 3	198	350
Higgins No. 10	440	520	Geyser-Kaltenbach	233	465
Higgins No. 15	284	503			

By consulting the logs it will be seen that the last four wells in the above list, together with the Higgins Nos. 4, 15, and 16, while showing a decided dominance of sand or gravel within the depths named, are almost devoid of sand within 100 or 200 feet of the surface. The largest proportions of sand and gravel are found in the Higgins Nos. 1 and 2. The section of the Higgins No. 1 shows 815 feet of sand out of 1,020 feet above the oil rock. Well No. 2 has 781 feet of sand and gravel out of a total depth of 1,006 feet, no considerable portion of the section having a dominance of clay. In the somewhat uncertain logs of wells Nos. 1 and 2 of the National Oil and Pipe Line Company, sand is given as the most abundant material to a depth of over 800 feet. At the other extreme may be placed the Denver-Beaumont well, with but 40 feet of sand beneath the 42 feet of surface clays, the balance of the section showing only an insignificant proportion of sand. "Sand rock" is occasionally mentioned, generally in beds of a very few feet. All the specimens seen of such sandstone have a calcareous cement. Such "rocks" are very local or concretionary.

GRAVEL.

While gravels occur in the sandy upper halves of a minority of the well sections obtained, they have no constant position, thickness, or character, and the correlation of such beds is not here attempted. Those gravels which have been thought to suggest some possibility of correlation are enumerated in the list given below. It is, of course, to be borne in mind that as reliable logs were obtained from only about one-twentieth of all the wells, this list of occurrences of gravel is correspondingly imperfect. It might be added that "very coarse sand" is mentioned in some other logs at horizons similar to those here named for the gravels, but the general omission of such mention in most logs is extremely adverse to any scheme of correlation.



VIEW OF A PORTION OF SPINDLETOP, 1902.

Gravels mentioned in Spindletop logs.

Well.	Thickness.	Depth.	Remarks.
	Feet.	*Feet.*	
Higgins No. 1	15	245-260	"Coarse sand with black pebbles;" occurs also deeper.
Higgins No. 15	7	270-277	No description.
Southern No. 4	68	255-428	Do.
Lucas	20	245-265	"Variously colored; from bean to goose-egg size."
Geyser-Kaltenbach	20	295-315	"Coarse;" occurs also deeper.

LIMESTONE.

In most of the logs there is frequent mention of "rock." As a rule, where not otherwise specified, this is understood to be limestone. When questioned, drillers frequently describe it as such. Most of the samples seen were limestone, a few being sandstone with calcareous cement. It is usually reported as occurring in beds 1 or 2 feet thick, but occasionally in 20 or 30 foot strata. Sometimes the degree of consolidation of these thick beds of rock may be exaggerated in the reports, but from the length of time required to drill through some of them it is believed that well-indurated beds of such thickness are occasionally encountered. In a note appended to the log of the Denver-Beaumont well, the contractor describes a very hard rock which was entered at a depth of 654 feet. This bed is 27 feet thick, and seventy-five days were required to drill through it. From the description given, the rock must be a very siliceous limestone. "Forty-three feet of steel were worn away in getting through this 27 feet." This statement, of course, refers to the wearing away of the bits. The reports of "soft rock," "soft white rock," "white clay," and "blue marl" probably refer to various shades of color and degrees of consolidation of the limy material.

SHELL BEDS.

"Shells," "shell beds," or "shell rock" are reported from most wells. Large fragments of shell rock were occasionally brought to the surface by blowouts or other accidental means. They indicate the existence of large accumulations of shells, such as occur at or near the surface at many places on the Coastal Plain. Shells are also reported as occurring mixed in all proportions with sand, rock, or clay. Shell beds, when thin, may form thoroughly indurated rocks. The thicker masses, reaching 40, 50, or 60 feet, are poorly cemented if at all, and generally do not consist of shells alone, but of shells mixed with sand or clay.

The relations of all the consolidated beds are such as to show that cementation has occurred most readily in the most calcareous material and where this material was comminuted and therefore easily dissolved. Where neighboring beds have been consolidated by the calcareous cement, or where calcareous concretions have been formed in these beds, the occurrence is in the permeable sands more frequently than in the more impervious clays.

CLAYS.

"Gumbo" is the common term by which most clays are reported.[a] There are occasional mentions of "shale," and from the descriptions given by drillers and contractors it would appear that occasional beds of the clays are sufficiently consolidated to justify the word shale. Probably in most cases, if not all, such occurrences are concretionary.

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[a] An intelligent driller, when asked to distinguish between clay and gumbo, defined the latter as a clay so sticky that instead of mixing with water as common clay does to form mud, it rolls up into balls.

LACK OF CONTINUITY.

On account of the lack of lateral continuity, individual beds noted in one well section can not be identified in another. An attempt to correlate the beds named in the accompanying logs will make this fact obvious. The first impression on finding that a bed noted in one well is not found at the same depth in another is that it has "dipped" or "pinched out," implying a lens-like form. These impressions are prevalent in oil fields and appear in the common phraseology of the operators, but are for the most part inaccurate. It should rather be assumed that any one bed shows a gradual change from place to place in the nature of its material.

AGE OF BEDS.

The exact age of these beds overlying the oil is a matter of much uncertainty. Of the few fossils found, none would indicate that the horizon of the oil is older than late Miocene, and the topmost beds are very recent. However, if the conception of the oil-bearing rock as given below (p. 119) is correct, the exact age of the strata in which it is included is not a matter of the first importance in determining the laws of its distribution on the Coastal Plain.

ROCKS CLOSELY ASSOCIATED WITH THE OIL.

Beneath the rocks above described are others whose presence is peculiarly characteristic of the mounds or dome structures which either yield oil or show close structural similarities to the oil fields. These rocks or minerals are porous limestone (or dolomite), sulphur, gypsum, salt, and pyrite with associated salts.

POROUS LIMESTONE.

The porous limestone is not the same as that described above as occurring in thin beds above the horizon of the oil rock, though gradations may occur between the two types (see p. 45). These thin beds are characteristically dense and seem to be in horizontal position. They are not crystalline, but show the ordinary dense texture resulting from induration of calcareous deposits. The limestone here referred to as characteristically associated with the oil bodies is sometimes dolomitic, and much of it is completely crystalline and porous or cavernous. Its upper surface is also extremely uneven, and its lower is perhaps equally so, though naturally the latter is but imperfectly explored.

Cavernous and oil-soaked fragments blown out from gushing wells, and differing from the beds passed through in drilling, may be supposed to fairly represent the rock which carries the oil. The crystalline character of this is evident. Among the workers in the field it is frequently compared to a light-colored maple sugar. Cavities may contain large crystals, or their walls may be drusy with calcite, though sometimes they contain sulphur (see p. 17). For a few inches, or even, it may be, a few feet, next to the upper surface, the limestone lacks the completely crystalline character, and resembles the dense, thin limestone beds found among the overlying clays. This narrow zone or crust of indefinite thickness (for the change is gradual) is spoken of as the "cap rock."

The dolomitic character of this porous rock varies. Doubtless the magnesium carbonate is always very subordinate to the calcium carbonate. No specimen was tested which did not effervesce freely with cold dilute hydrochloric acid without pulverizing the rock. Prof. F. C. Thiele, of Beaumont, has found no proportions of magnesia to lime greater than 1 to 40. The analysis here given is of the so-called "cap rock," which may be either the dense crust of the oil-bearing rock or the reservoir rock itself.

Analysis of the limestone forming the cap rock of the Beaumont oil.[a]

	Per cent.
Silica	0.40
Oxide of iron	.50
Oxide of alumina	
Lime	54.89
Magnesia	Trace.
Sulphur, as free sulphur and in organic combination	1.58
Sulphur, as sulphuric acid in combination	.21
Carbonic acid	42.45
Total	100.03

The openings seen in hand specimens are of all sizes, from the minutest pores to cavities more than an inch in diameter. The sudden dropping of tools through supposed cavities of several feet, which is discussed elsewhere, does not necessarily indicate the presence of such large openings. On the other hand, there is no reason to deny the existence of cavities much larger than those seen in hand specimens. Doubtless very large masses of this oil rock may have a porosity of over one-third the total volume.

Computations based on the amount of oil produced indicate that the reservoir rock must be extremely porous or cavernous. The 37,000,000 barrels of oil already taken from this pool [b] would cover the area of the productive field to a depth of 22 feet. To afford room for this amount of fluid would require a rock 66 feet thick, one-third of its volume being pore space. Therefore, unless the average thickness of the oil-bearing limestone is greater than it has been believed to be, its average porosity must exceed 33 per cent, or oil must have come in from a totally unknown source. If the average porosity exceeds 33 per cent, there must be large spots in which more than one-half the total volume is pore space, for the rock is locally dense. Large cores of similar rock taken from other mounds sometimes show more than 33 per cent of pore space, the pores or caverns being either empty or filled with sulphur.

So far as observed, a specimen taken from the immediate upper crust has essentially the same density, hardness, and constitution as the local limestones in the overlying beds. The thickness of this crust may be inferred from the depth to which wells are drilled into the rock before setting casings. It may safely be assumed that in all cases there are at least a few inches of such a crust. Its thickness may reach many feet, and at places the entire mass of the rock may be of the dense character of the crust.

Sometimes well-rounded or multiplex concretions of pure crystalline limestone of the maple-sugar appearance are carried to the surface by blow-outs. It is not possible to say positively from what matrix these come, but they belong near the horizon of the oil rock and probably come from a marly stratum.

An understanding of the exact nature and origin of the porous limestone would be much facilitated by a clear picture of the exact forms of the bodies in which it occurs. It might have been hoped that where wells were drilled so close that the timbers of neighboring derricks touched or interlocked, a comparison of depths at which the rock was reached would give a fairly exact picture of the form of its upper surface. Unfortunately, in the violent rush of well drilling in the most closely perforated portion of the field, the methods of work and of making reports were not such as to insure accuracy within 10, 20, or even 30 feet. If reports could be accepted as given (generally orally), the depth to cap rock in neighboring wells might differ as much as 20 or 30 feet within a horizontal distance of the same amount. This would require that the oil rock should have an extremely lumpy or hummocky upper surface or should interlock in some way with the overlying formation. While making large allowance for the unreliable character of most of these hurried reports, it still seems necessary to conclude, from the observations of some careful contractors and good observers, that the upper surface of the oil rock has such a lumpy or (in a very large way) botryoidal form. In addition, this irregularity of surface seems to be attended by overlying or outlying concretions and possibly by branching veins. The oil rock does not seem to have on its lower side any such dense crust as that which is encountered above.

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[a] Analysis by Mr. S. H. Worrell; see Phillips, Wm. B., Texas petroleum: Bull. Univ. Texas Mineral Survey No. 1, 1900, p. 27.

[b] Before January 1, 1905.

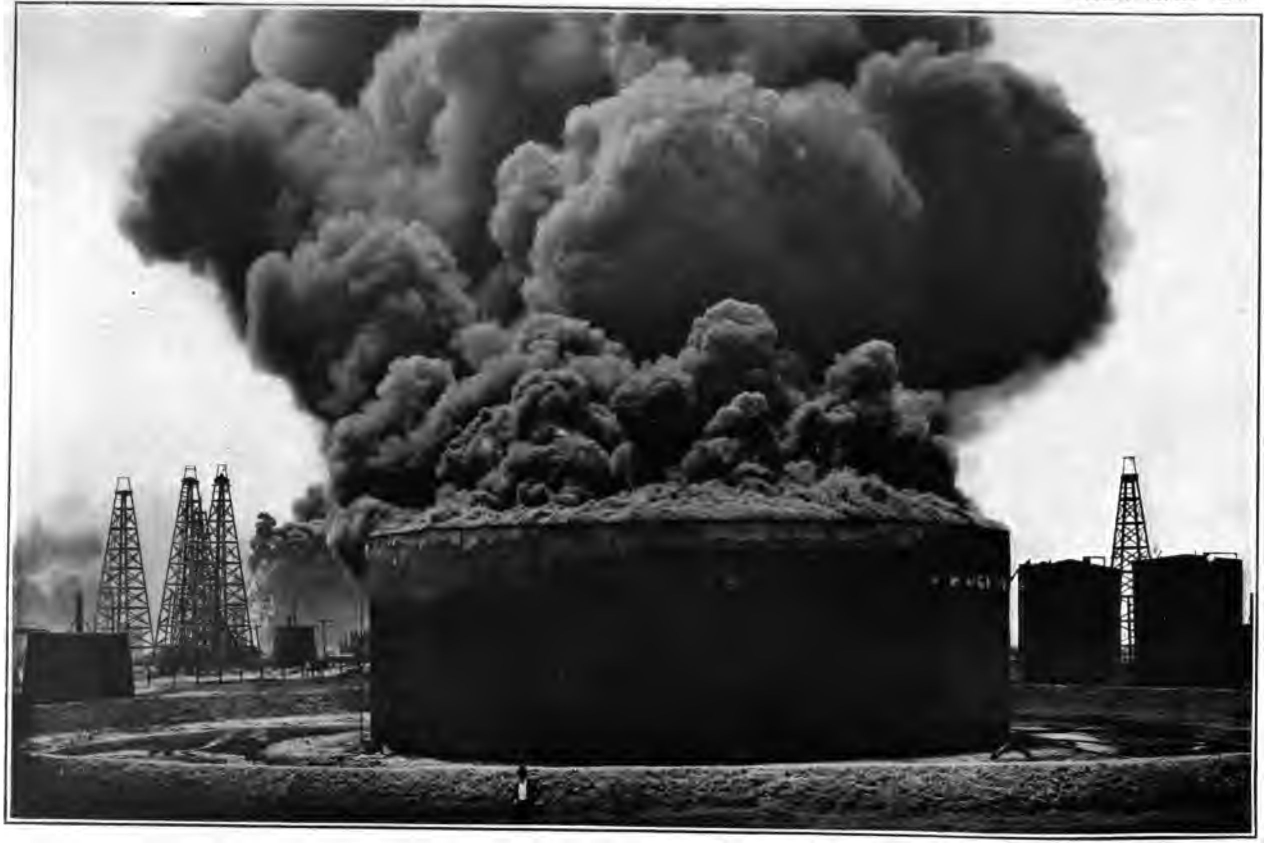
FORMATION BETWEEN OIL HORIZONS.

There are in many wells two oil-bearing horizons, the oil in both cases coming from the same kind of porous limestone, the two horizons being separated by a barren zone, which in some places attains a thickness of almost 200 feet, though in most cases it is less than 100 feet thick. Concerning the nature of the material between two oil-bearing horizons, there is fairly general agreement. Mr. A. W. Hamill, a driller and contractor, who has observed the formations with some care, speaks of this material in the Keith-Ward tract as a "white, limy stuff" resembling gypsum. It is generally, though not always, unconsolidated. It contains many concretions, commonly spoken of among drillers as "bowlders". These are liable to loosen and turn under the bit and give much trouble in drilling. The specimens seen of these "bowlders" are all limestone. In the Higgins No. 6 the formation from 1,009 feet to 1,024 feet, occupying the space between two "oil sands," was a "hard, bluish, porous rock." In the Gladys No. 3 were "60 or 70 feet of white limestone" intervening between two oil horizons. In block 33, Gladys City (the Yellow Pine tract), the corresponding material is referred to as "generally whitish or gray, limy stuff, not always soft." An occasional streak of "blue shale" is also mentioned in this locality. In the McFaddin No. 2 about 15 feet of "gumbo" separates two oil-bearing levels. In some cases, as in the National Oil and Pipe Line Company's well No. 7, such a gumbo parting is but 1 or 2 feet thick. The mention of gypsum may be assumed to be only by way of superficial comparison, though gypsum is probably found at greater depths in some of the same wells. On the whole, the language employed in description, together with the evidence of the calcareous concretions, points strongly to a marly substance more or less clayey and having, in different wells, different degrees of consolidation.

FORMATION BENEATH THE OIL ROCK.

Testimony concerning the material beneath the lower oil horizon is divided, some of it being in perfect agreement with that concerning the material just described, while other reports point to the presence of a white sand beneath the lowest oil. "Very hard clay" is mentioned at one place (Higgins No. 7); "gumbo underlain by laminated sandstone" at another (McFaddin No. 25); "soft sulphur mud alternating with hard limestone" at another (Higgins No. 5); "white soft sands" at another (Higgins No. 10); "white lime rock" at another (Higgins No. 3), were the same material intervenes between two masses of the oil rock. "White, limy porous rock" was entered by one of the Cartwright wells after passing through a 2-foot oil-bearing stratum, which may be the representative at that place of the regular oil rock. "White, limy or gypsum-like material, not hard as limestone proper should be," "having loose bowlders" (concretions), was found in Gladys No. 1, where it was drilled into for 50 feet below a 40-foot oil rock. "Soapstone" is said by a reliable observer to underlie the lowest oil rock in the Iowa-Beaumont well (Keith-Ward tract), but the same observer uses the word soapstone to describe the "white, limy stuff" with concretions, found between the oil horizons in the same tract, and it is therefore believed that the word should be similarly interpreted in the other case. In two wells—the Confederated No. 3 and the Gladys No. 6—the drill stopped in white sand at some distance below the oil rock, but the bed immediately below the latter is not described.

The descriptions cited above make it quite probable that in the main the subjacent neighbor of the oil rock is of the same calcareous nature as that which intervenes between two oil horizons, where two are found. It is subject to various degrees of consolidation, and may locally pass into a stiff clay or contain clay streaks. The mention of white sand



FIRE IN SPINDLETOP OIL FIELD, SEPTEMBER, 1902.

may refer to the same substance, but inasmuch as trustworthy observers have described occurrences in different wells differently, it is more probable that the material is locally sandy, or it may even be that the sand exists in separate bodies of lens-like form. The superficial resemblance of light-colored marl to gypsum is manifest, and the latter is no doubt found both pure and intermixed (see p. 17), but these masses of "soft limy stuff" are not so interpreted.

SULPHUR.

A characteristic constituent of many of the mounds is sulphur. Though not found in all wells at Spindletop, it is very common, either pure or as an admixture. Deposits of sulphur occur both above and below the horizon of the oil, though of necessity it is less known in the latter position. Most wells went but a few feet into the oil rock, and therefore the knowledge of what lies deeper is very limited. From the nature of the cuttings brought up by the rotary method of drilling, the reports of "solid" or "pure" sulphur must be received with some allowance. The following are some characteristic illustrations of its occurrence at Spindletop:

Well No. 1 of the National Oil and Pipe Line Company reported 40 feet of "pure sulphur" immediately above the cap rock. The same 40 feet of solid sulphur appears in the logs of wells Nos. 2 and 3 of this company, though the wells are separated by some hundreds of feet. The observations on which the logs of these three wells are founded were made under certain disadvantages which impair the value of the records. In well No. 2 the report is varied by the appearance of 26 feet of "sand and sulphur" between the 40 feet of solid sulphur and the oil rock. In the Higgins No. 5, 8 feet (1,020 to 1,028) of supposedly pure sulphur occurs between beds of hard rock, being separated by 17 feet of the latter from the main oil-bearing rock below. There are also 10 feet of "soft sulphur mud" above the sulphur and separated from it by 5 feet of hard rock, presumably a bed of limestone. The chief oil-bearing horizon (1,045 to 1,061 feet) is also described as "soft and sulphury." In the Higgins No. 1 are 10 feet of "sulphur rock" at the bottom of the well (1,030 to 1,040 feet) underlying the main oil-bearing bed, which is here but 10 feet thick. The Southern No. 4 encountered 1 foot of sulphur just above the cap rock, which is here 982 feet below the surface. Higher up in the same well 3 feet (845 to 848) of sulphur are reported. On the west side of the Yellow Pine tract (block 33 of Gladys City) 15 feet of "pure sulphur" (970 to 985) are said to underlie the main oil horizon. Similar deposits on the east side of the block have the same relations. The log of the Heywood No. 2 gives 33 feet of "sulphur rock" immediately above the oil rock, which was struck at 950 feet. This record adds credibility to that of the National No. 1, which is less than 200 feet distant. The Heywood No. 1 is said to have the same formation in the same relations, but the thickness is not recorded. The No. 3 well of the same company reports "sulphur rock" at four horizons, with thicknesses of 10, 15, 8, and 20 feet respectively, the lowest sulphur formation resting directly upon the oil rock. Seventy feet of sulphur are claimed for the Gladys No. 3, the location being above the oil. A few inches of pure sulphur were found in block 44, of Gladys City. "Solid sulphur 100 feet thick" is reported near the center of the field in an isolated dry well, which is quite surrounded by producers. The depth of this alleged deposit is greater than that of the surrounding oil zone.

In most of the wells cited above sulphur was supposed to be found unmixed with earthy matter. Where found remote from the oil rock (generally above) it is commonly reported as mixed with sand and clay, and this may also be the case in beds in contact with the oil rock. In the Higgins No. 7 there are 24 feet of "sulphur and white rock mixed" immediately above the oil rock, which was found here at 746 feet. In the Higgins No. 10 occur 8 feet (930 to 938) of "soft sulphur and white and gray rock," separated by 34 feet from the top of the oil-bearing rock. Some wells on the adjacent prairie beyond the limits of the field have encountered small proportions of sulphur in beds of sand and clay, but "pure" sulphur has not been discovered outside the territory underlain by the cavernous limestone.

The above enumeration of occurrences of supposedly pure sulphur shows the basis for the statements made by well-informed operators to the effect that when sulphur is encountered in the unmixed form it is generally on or in the oil rock. The fact is significant that out of the comparatively small number of wells which were drilled to depths beyond the oil horizon three of those whose logs were obtained encountered sulphur beneath the oil. At all events, in the present state of our knowledge it is unsafe to assign a place to sulphur deposits above rather than below the oil. The great sulphur deposit in a mound similar to Spindletop at Sulphur, La., is found beneath small quantities of oil, and no oil is known to underlie the sulphur. It is not improbable that if the few hundred feet next beneath the main oil horizon at Spindletop were as thoroughly explored as those above, the prevailing position of the sulphur would be found to be below the oil.

Despite the popular impression there is small ground for assuming that the sulphur occurs in definite beds or continuous masses of large size. Samples conveyed to the surface by blow-outs or taken out as cores show pure sulphur and limestone as parts of the same chunk. Where there is any evident structural relation, as in the McFaddin well No. 13, the sulphur fills cavities in the limestone which are in every way similar to the cavities found in the best oil-bearing rock. The latter, in fact, are not infrequently lined with small sulphur crystals, just as in other cases they are lined with small calcite crystals. Gushers have ejected well-formed crystals of sulphur, more than an inch in length, indicating the existence of only partially filled cavities of still larger dimensions. Locally the limestone may be extraordinarily rich in sulphur-filled cavities, or the drill may strike some such masses of extraordinary size; there may even be some veins or "chimneys" filled with the same substance, but direct proof of such is wanting.

An inspection of the overlying beds shows that in nearly all cases the sulphur, when not found in the oil rock itself, is covered by a dense rock, either clay or limestone, and therefore occupies a position in which a body of oil might have been retained. There are a few cases, as in the Heywood well No. 3, where beds containing much sulphur are overlain by sand, but it must also be borne in mind that oil is sometimes reported as occurring beneath a barren sand. The explanation which at once suggests itself is that an impervious parting has been overlooked. The significant fact is that in the case of sulphur, as in that of oil, the reports of such relations are exceptional.

GYPSUM.

Gypsum is mentioned in a considerable number of reports from Spindletop, but it is impossible to verify its existence at this time because of the inaccurate use of the term and the want of samples. It is poorly discriminated by drillers from "soapstone" and marl. This is evident from the reports of gypsum abounding in shell remains. While other materials may thus be wrongly reported as "gyp," gypsum is liable to be classed as "rock" where found. Of the two deep wells on the hill, the Iowa-Beaumont reports "soapstone" beneath the oil rock to 1,200 feet, and the Higgins No. 3 reports mostly "white lime," with comparatively small amounts of sand and rock, to 1,647 feet. Either of these reports might cover a large amount of gypsum, but there is no direct evidence to that effect.

While direct proof by samples is impossible at the present time, careful observers who examined many samples during the early life of the field do not hesitate to speak confidently of the association of gypsum with oil-bearing rock. Hayes and Kennedy[a] make the statement: "From some of the wells, along with the dolomite, large pieces of crystalline gypsum or selenite have been thrown out by the escaping oil. Their surfaces are always deeply corroded, giving evidence that they have been subjected to the action of some solvent." Lee Hager speaks confidently of the presence of gypsum, or, rather more frequently, of anhydrite, beneath the oil horizon. It is his impression that the very thick strata, 50 to 100 feet, reported as gypsum are more frequently composed of thin beds of gypsum interbedded with clays or sands. The reports of gypsum, either in this condition or as selenite crystals, do not furnish an exact parallel to its occurrence at some other mounds, where it is found as a massive rock, sometimes hundreds of feet thick (see p. 80), but such occurrences at Spindletop might easily be referred to by the rather vague reports of "soapstone" or "limy stuff." The normal position of gypsum when occurring in great masses seems to be some distance below the limestone. The existence of well-developed selenite crystals suggests that the gypsum sometimes occurs in cavities, presumably those of the limestone, though the crystals may have developed in loose sediments.

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[a] Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey No. 212, 1903, p. 71.

ROCK SALT.

Both the deep wells went into rock salt. The Iowa-Beaumont entered "pure salt" at 1,200 feet and continued to 1,790 feet, stopping in the same material. The Higgins No. 3, entering salt at 1,647 feet, continued to 1,990 feet without encountering any other substance. The analogy of certain other mounds would create a presumption in favor of gypsum above the salt if the former is to be found at all (see p. 17). An exceptional case of salt above the oil appears in the Higgins well No. 19, where a 10-foot bed of "rock salt" is reported at a depth of about 600 feet. Its purity is uncertain.

PYRITE.

In small quantities iron pyrite is found at almost all depths, sometimes scattered through the sand, sometimes concentrated in nodules or so strongly impregnating certain thin beds as to make a serious barrier to the rotary drill. It took eleven days to drill through a 6-foot layer of this character in the Higgins well No. 14. This bed was encountered at 600 feet. In the Higgins well No. 9 the same kind of rock, met with at various levels below 800 feet, is described as occurring in "bowlders." Pyrite is most frequently mentioned as occurring just above the oil, the oil rock itself frequently containing admixtures of it. A zone overlying the oil rock in the McFaddin well No. 7 is composed of interstratified rock (presumably limestone) and pyrite. In the McFaddin No. 5, a dry hole on the north side, there were several hundred feet in which the same materials were interstratified. The depth of the abundant pyrite in this well is about that at which the oil should have been expected. The limestone mentioned as interstratified with pyrite is not, however, the porous or cavernous rock which carries the oil, but a dense rock like the thin limestone beds found above the oil.

POSITION OF THE OIL.

So far as the petroleum can be assigned to a constant position among the substances discussed above, it may be said to belong to the caverns and pores of the principal limestone. Far the larger part of the oil has been found in this position, and over most of the area of Spindletop no oil from any other horizon has been developed. Only "showings" are reported from the sandy beds above. In the haste to reach the well-known rock below, little attention was paid to these showings, and it can not be known how much oil, if any, they might have yielded. On the other hand, a very considerable productive area on the west side of the field has yielded little or no oil from the porous limestone, if, indeed, the latter is present. With the exception of one or two wells which seem to have entered the regular oil rock, all the wells in this vicinity obtain their oil from sands inclosed between clays. These sands have diverse depths in different wells, and it is quite probable that they are of very limited lateral extent and that near-by wells derive their oil from different bodies of sand.

It should be plainly recognized that the Spindletop pool contains oil in two distinct relations—in the porous limestone and in loose sands. This is an essential consideration if this field is to be compared with other fields of the Gulf Coastal Plain. In this connection it is also to be noted that the destructive blow-outs of gas by which some wells have been ruined have come from beds some distance above the porous oil-bearing limestone.

GENERALIZED COLUMN.

So far as the facts detailed above warrant a statement concerning the general relations of the materials disclosed by the Spindletop wells, these materials may be said to occupy more or less distinct levels and to be arranged in the following order:

1. Sands, clays, and thin limestones; occasional admixtures of sulphur and pyrite.
2. Iron pyrite, most abundant just above the cavernous limestone.
3. Cavernous limestone containing oil and sulphur.
4. Gypsum, which may be massive, interlaminated or mixed with sand or clay.
5. Rock salt to an unknown depth, probably pure.

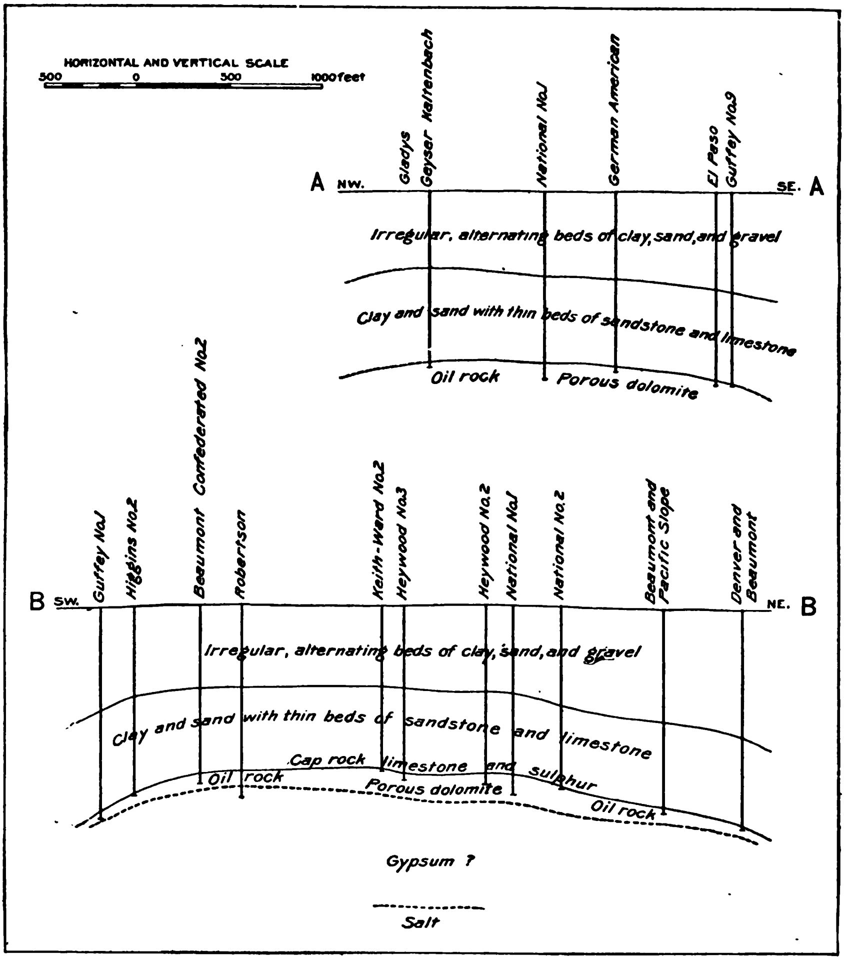
HORIZONTAL AND VERTICAL SCALE
500 0 500 1000 feet
A NW.
Gladys
Geyser Kaltenbach
National No.1
German American
El Paso
Guffey No.9
SE. A
Irregular, alternating beds of clay, sand, and gravel
Clay and sand with thin beds of sandstone and limestone
Oil rock
Porous dolomite
B SW.
Guffey No.1
Higgins No.2
Beaumont Confederated No.2
Robertson
Keith-Ward No.2
Heywood No.3
Heywood No.2
National No.1
National No.2
Beaumont and Pacific Slope
Denver and Beaumont
NE. B
Irregular, alternating beds of clay, sand, and gravel
Clay and sand with thin beds of sandstone and limestone
Cap rock limestone and sulphur
Oil rock
Porous dolomite
Oil rock
Gypsum ?
Salt

FIG. 1.—Section of Spindletop oil pool. (See map, Pl. II, p. 18.)

The zone here referred to as No. 3 is complex and must be understood as embracing much unconsolidated limy sediment. No definite statement can be made concerning the relative positions of the sulphur and the oil, except that the two occur in similar relations to the sediments and crystalline limestone.

GEOLOGIC STRUCTURE.

There still remains some obscurity about the geologic structure of Spindletop and similar mounds. There is no reason to doubt that there is some upward bulging in the form of a dome (see fig. 1). The areal extent of this structural dome is substantially that of the surficial elevation. The height of the uplift affecting any given horizon can be stated only when that horizon has been clearly discriminated over the entire field and its depth ascertained both on the top of the dome and beyond its limits, where the beds are horizontal. Because of the lack of lateral continuity in the character of the beds, such data are difficult to obtain. The principal dependence must be placed on data pertaining to the oil-bearing rock because this formation is best known and probably the most continuous.

TWO OR MORE OIL HORIZONS.

The difficulty in an accurate delineation of the dome structure arises from the presence (locally) of more than one horizon of the genuine oil rock. Each has considerable continuity throughout certain parts of the field and there is some uncertainty as to which should be correlated with the single oil-bearing rock near the edges of the mound. One such area of two oil horizons embraces much of the Keith-Ward tract and is apparently continuous to the north far enough to include blocks 21 and 33, Gladys City. The porous oil rock is reached anywhere in the northern part of the Keith-Ward area at less than 900 feet, and in some wells at less than 800 feet. The first oil-bearing rock encountered may have a thickness of from 20 to 40 feet. Below it is the marly material described above as having various degrees of consolidation and containing calcareous concretions usually spoken of as loose bowlders. At about 1,000 feet, or frequently less, the porous crystalline oil rock is found again. A majority of the reports say that at this lower level the oil rock is incrusted by a hard "cap rock" similar to that of the higher stratum, and that the two horizons are not distinguishable by any physical characteristics.

In block 21, Gladys City, the true oil rock, yielding large quantities of oil, is said to be found at a minimum depth of 740 feet and to have a thickness of 40 feet. Most of the wells from the upper horizon in this block are deeper than this, the oil being found at varying depths, averaging about 800 feet. Here again a lower stratum is reached at between 900 and 1,000 feet. The same statements, with little change of figures, apply to block 33 (the Yellow Pine tract).

The Gladys well No. 3, situated between the Keith-Ward tract and block 21, found oil at 760 feet, being one of the shallowest wells in the field. A lower oil stratum was reached by this same well between 900 and 1,000 feet. Gladys Nos. 8 and 18 also show two oil strata similar to those in No. 3.

Some wells near the edge of the dome show a similar duplication of oil-bearing horizons. In the Higgins No. 5 an upper showing of oil at 983 to 1,005 feet is separated from the principal oil, which is found at 1,045 feet. A similar separation has been pointed out in the Higgins No. 6, while partings of less magnitude have been noted in the McFaddin No. 2 and the National Oil and Pipe Line Company's well No. 7.

Situated somewhat centrally in the area where the two oil horizons are noted are other wells, e. g., the Gladys No. 4, in which the lower oil was reached without passing any indication of a higher oil-bearing stratum. It would seem from this and other similar occurrences that the lower stratum is the more continuous, while the upper ones are local, and that therefore, in determining the elevation of the structural dome, it would be best to correlate the lower horizon at the center of the area with the single formation which is found at the edge. It is more probable, however, that neither formation is entirely continuous, but that there is a zone from 100 to 200 feet in thickness which contains numerous masses of porous rock at different depths. It is not therefore certain that either oil horizon at the center of the field can be exactly correlated with that around the edges.

DEPTHS AND DIPS OF THE OIL ROCK.

In the following statements concerning the structural relations of the oil rock it is assumed, for convenience, that the lower porous limestone near the middle of the field is continuous with the single stratum found near the edges of the dome. It must be understood, however, that in speaking of dips it is not intended to imply that the inclined formation is one and the same bed at the same stratigraphic horizon throughout. A difference of depth which may be spoken of here as indicating an inclination of the rock may mean that entirely distinct rock bodies were encountered in different wells.

A little north of the center of the field the lowest oil rock seems to be found nearer the surface than at any other place. It is entered here by the wells on the west boundary of the National Oil and Pipe Line Company's tract at a depth of less than 900 feet. Within 500 feet to the northeast the rock was found to be from 25 to 50 feet deeper. One thousand feet to the north the Denver-Beaumont well reached what may fairly be correlated with the porous oil limestone at 1,104 feet. The fall toward the northwest from the assumed center (if the same horizon is represented by the deeper oil in the Yellow Pine tract) is perhaps 100 feet in a distance of 500 to 600 feet. The rock is little if any deeper in block 21 than in block 33, though the former is 1,000 feet west from the assumed crest of the dome. Concerning the west side of the field, reference has already been made to the wells which pumped oil from sand beds in blocks 5, 6, and 11, Gladys City. These wells did not find the oil limestone, though some of them are 1,100 feet deep. Southeast from the supposed highest point of the dome the level soon falls below 900 feet in the west corner of the Hogg-Swayne tract. The average depth of the oil rock here is probably 50 feet greater than on the supposed top of the dome 500 feet to the northwest. Southwest from the National and Hogg-Swayne tracts is the central portion of the field, including and extending beyond the two tracts of the Higgins Oil and Fuel Company. Ignoring for the present the extreme edges of this area we may say that the entire fall in nearly one-half mile to the southwest from the highest part of the dome does not exceed 50 or 60 feet. It is steepest near the center of the field and becomes very small or disappears entirely for a considerable distance. In certain localities the depth of oil would indicate a greater inclination of the oil-bearing rock, but such instances are exceptional. There may, indeed, be a secondary dome at the southwest end of the field, but to delineate such would require a refinement not possible from the data. On the west side of the field, in the vicinity of the Sabine and East Texas Railroad station, the true oil rock is recognized in only one well (block 44). It was found here at 978 feet, which is substantially the same depth at which it was found in the southwest end of the field. There can be no certainty about the correlation of the limestone in this well with that found farther east. Other wells in this vicinity have gone deeper, but neither at this horizon nor at any other have they reached any recognized equivalent of the porous oil-bearing limestone.

It is noteworthy that a large number of wells near the edges of the dome found the oil rock at distinctly greater depths than those named above. The depths given above for the Hogg-Swayne tract are applicable to the western third of that tract.[a] East of a line running north by west and passing somewhat west of the center of the tract the oil rock has a decided dip in an easterly direction. At places the increased depth of the oil horizon is as much as 70 feet in a distance of 200 feet, though such sharp dips may have borrowed steepness from the local irregularities of the upper surface of the limestone. Probably it would not be safe to assign to this edge of the dome a general dip greater than 1 foot in 4, and that for only a short distance. Exploration extends but little to the east of this so-called "monocline," and it is not known that the total drop exceeds 60 or 70 feet. It is said that the character of the oil rock remains the same wherever found on this side of the field.

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[a] In referring to the map it should be noted that the boundaries of this and other rectangular tracts do not run with the points of the compass and that the cardinal directions are not parallel with the margins of the map.

On the south side of the field the McFaddin wells and Higgins Nos. 5 and 6 all found oil considerably deeper than it was found nearer the center of the field, generally at about 1,000 feet and frequently lower. Here, however, the true oil limestone was generally found at at least two different depths in the same well and some oil was obtained from each horizon. The higher levels, if correlated with the most productive levels in the body of the field, would indicate a slight dip away from the mound. If the lower and more productive levels be assumed to be continuous with the lower horizons in the body of the field, a marked southeastward dip is indicated, though the fall would not be so abrupt as that in the Hogg-Swayne tract.

Two wells in the Hebert tract, located on the flat south of the mound, found the oil rock at 996 feet, which is substantially the depth of the lower horizon in the Keith-Ward tract. West of these the group of Trembly wells and those of the Southern Drill Company reveal a very slight dip to the south or southwest, the greatest depth at which oil was found being 1,010 feet. A few hundred feet farther southwest the oil rock is probably represented in the Hamilton-Prince well by about 4 feet of limestone struck at 1,020 feet, which yielded no oil. The Lone Acre well, 150 feet farther west, went 1,240 feet and found no rock. One hundred feet east of the Hamilton-Prince Mr. Benjamin Andrews found the undoubted oil rock at 1,010 feet and obtained some oil. A well drilled by Mr. Andrews about halfway between these two last named found a limestone at a depth which indicated a slight westerly dip, but the rock lacked the porosity of the oil rock and contained no oil. Three hundred feet farther south the eastern one of two Cartwright wells found, at 1,111 feet, a 2-foot oil-bearing stratum which may represent the oil limestone. The other of these wells, 140 feet farther west, showed nothing which could be identified with the stratum in question.

DIMENSIONS OF THE DOME.

From these depths it appears that the Spindletop structural dome is of very gentle slope and small height. A generalized section from the Cartwright wells on the south-southwest to the Denver-Beaumont well on the north-northeast would show an arching of a little more than 200 feet in a distance of 4,000 feet, the dip to the north being considerably steeper than that to the south. An east-west cross section would be of similar dimensions and would show the steepest dip on the dome, namely, that of the abrupt monocline running through the Hogg-Swayne tract, where, for a horizontal distance of 200 or 300 feet, the dip may be as great as 1 foot in 4. It is to be understood that these statements about cross sections ignore not only all the limestone formations above the lowest, but all the local roughness of the surface. The dimensions of the dome are taken from the upper surface of the lowest representative of the oil rock, this member being assumed to be continuous, or at least far more likely to be continuous than any other member.

The height of the dome as regards any bed below the oil limestone is even less than that given above, for the reason that the limestone formation is thickest at the center. From well records on the south side it appears that the limestone is very thin at the edges of the mound, while beneath the mound the thickness of the lowest oil rock alone is considerable. There are 40 feet of it in the Gladys No. 1 and 20 feet in the Higgins No. 3. It is quite safe, therefore, to affirm that within the explored area the amount of differential uplift of beds below the oil-bearing limestone is well within 200 feet. It is significant that in two wells, the Cartwright on the south and the Denver-Beaumont on the north, in which the supposed oil rock was encountered some hundreds of feet beyond the limits of the mound, the depth of the rock is substantially the same, being in each case a little more than 1,100 feet.

If the entire zone in which oil occurs be considered as a unit, its greatest thickness and the highest part of the dome are in the Keith-Ward tract and adjacent territory to the north and northwest. Looked at in this way, the maximum thickness of the reservoir rock is over 200 feet, and its upper surface forms a dome fully 300 feet high. Beds above the limestone, if conformable with it, would of necessity be domed to the same extent. The lack of lateral continuity in the beds makes evidence on this point very difficult. There is no collateral evidence of so great an uplift of the overlying beds.

STRUCTURE BEYOND THE LIMITS OF THE DOME.

Beyond the immediate limits of the oil field the far deeper wells of the surrounding prairie have not found any formation to correspond to the porous oil-bearing limestone. The western one of the two Cartwright wells, 1,424 feet deep, did not pass the oil rock, though only 140 feet farther east it seems to be feebly represented at 1,111 feet. The Lone Acre well, northwest of. the Cartwright, went 1,240 feet without finding the rock in question, though it is quite certain that the Hamilton-Price well, which is just 150 feet away in the direction of the mound, found the rock at 1,020 feet. If the McFaddin No. 5 (near Spindletop avenue northeast) found the rock at all, it was dense and hard and not to be distinguished from the thin limestone beds which occur in the overlying sands and clays. Four hundred feet to the southwest of this well and also 600 feet to the northwest (in the Denver-Beaumont well) the oil rock is recognizable. In the northwest side of the hill no deep well nearer than 1,500 feet from the developed field affords information. At that distance the Chicago Crude was sunk 2,100 feet without finding the oil rock. On the northeast side the big Jumbo is 1,100 feet from the nearest productive well (the Denver-Beaumont). It is 2,000 feet deep, but did not find the formation in question. Nearly all the wells in the barren area surrounding Spindletop passed through limestone, sometimes in thick strata and at great depths, but its character is always that of the thin limestones above the oil.

The structure beyond the immediate limits of the known dome may be considered with reference to three possibilities: (1) The dip of the oil formation may be so great as to carry it beyond the reach of the deepest wells. (2) The rock may be horizontal outside the limits within which it is shown, but have its character changed within a narrow space to that of the ordinary Coastal Plain deposits. (3) The rock may thin out and disappear, the entire formation having the form of a lens, concave below and convex above. It is sufficient here to express the belief that a combination of the second and third hypotheses contains the essential truth. The first hypothesis, besides being inherently improbable on account of the magnitude and steepness of the dips required, is unsupported by any collateral evidence within this field. Its only claims to consideration are based on (1) the failure to find the oil rock beyond certain limits and (2) a supposed analogy with certain salines of Louisiana and eastern Texas, where the quaquaversal dip is marked, but where crustal deformation is manifestly far more intense than at this point.

GAS.

FROM ABOVE THE OIL.

At almost all depths small showings of gas were encountered. Its appearance, even at the surface, has been noted under "Surface indications" (p. 18). Except near the depth of the oil, however, gas pressures are very slight. A stratum above the oil, though entirely separate from it, frequently produced gas under remarkable pressures, in some cases dry, in others carrying small quantities of oil.

It was from this horizon that the destructive "blow-outs" occurred. In some such cases the machinery was wrecked and the casing driven from the well. The derrick floor and surrounding ground were covered to a depth of several feet with sand and mud and the hole was ruined. These violent eruptions might continue for a few hours and then cease entirely, partly, perhaps, by reason of the clogging of the well, partly on account of the exhaustion of the gas pocket. The gas above the oil is sometimes described as coming from a "mucky sand" having sufficient plasticity to be molded in the hand. The beds separating it from the porous oil-bearing rock below appear, where described at all, to be of an impervious nature.

GAS FROM THE HORIZON OF THE OIL.

Great quantities of gas come out with the oil itself, doubtless from the same cavities of the porous limestone, or the gas may have been absorbed in the oil under enormous pressures. Men at work in the oil fields generally speak of this gas which comes out with the oil as differing from the dry gas found higher. The former is spoken of as poisonous, while the latter is thought to be harmless. The distinguishing characteristic of the lower and deadly gas is probably sufficiently accounted for by the following quotation from Hayes and Kennedy:[a] "This gas contains a large proportion of hydrogen sulphide and its poisonous qualities are intensified by its being saturated with petroleum vapor. Petroleum vapor has the effect of rendering persons inhaling it unconscious, and if one remains under its influence for any length of time death ensues. The combination of hydrogen sulphide and petroleum vapor issuing from the wells is such as to render death almost instantaneous." Some deaths occurred at Spindletop from this cause and in a large number of cases death was averted only by a timely resuscitation. The effect of the saturated gas on the eyes is very painful and injurious, lasting a number of days. The expression "gassed eyes" is thoroughly understood in the Texas oil fields and regrettably familiar.

It is the expansive force of this gas which causes the phenomenon of gushing. The oil and gas come out together in a spray, which may rise to several times the height of the derrick.

SALT WATER.

The first appearance of salt water in the Spindletop field was in the great blow-out of the McFaddin No. 4. The gas was struck at 918 feet, which is considerably higher than the local level of the oil. Elsewhere on Spindletop salt water was not found above the oil. It is uncertain whether the vicinity of this well is exceptional in this respect or whether the explosive expansion of the gas rent the rock in such a way as to connect the well with a deeper source of salt water. Salt water first began to follow the exhaustion of the oil in the wells of the Export Oil and Pipe Line Company, at the north corner of the Hogg-Swayne tract. Later this became the common experience in the deeper wells around the edges of the field. In a general way the area invaded by salt water spread toward the center of the field, but the advance was extremely irregular and the rate of advance on different sides was not uniform. Before the general occupation of the Hogg-Swayne tract by salt water an occasional well encountered it by being drilled too deep. Some wells in the earlier life of the field were exhausted and abandoned before the advent of salt water. This was notably the case in the Yellow Pine tract. At the present time, however, salt water has invaded all parts of the field, and the amount of it pumped greatly exceeds that of the oil.

There has been occasional freakish behavior of wells, as in the case of the Higgins No. 10, which, after producing oil at the rate of 600 barrels a day, suddenly began to produce salt water, which continued for ninety-four days, after which time the well produced oil steadily with no admixture of water.

PRODUCTION.

QUANTITY OF OIL.

In the first four years of its life the Spindletop field produced 34,000,000 barrels of oil. Including the production of the fifth year and the amount wasted for lack of storage facilities in the early days of the field, the total amount brought to the surface was at least 37,000,000 barrels. If this amount were contained in a tank having a base equal to the area of the field the depth of the oil would approximate 22 feet. Estimates of the yield of gushing wells are generally greatly exaggerated. In one instance, however, that of the Heywood No. 2, the actual flow into the tank is given by a careful authority[b] as 8,000 barrels within two hours, or at the rate of 96,000 barrels a day. In ten months it produced 1,395,000 barrels. The original Lucas gusher (McFaddin No. 1) is said to have flowed at an initial rate of 75,000 barrels per day, but this statement is not based upon measurements.

The average life of flowing wells in the Spindletop field was short, frequently but a few weeks and rarely more than a few months, with constantly diminishing output. When flowing ceased, many of the wells were put to pumping, but many others were abandoned. Late in 1904 there was a revival of drilling operations on the southwest side of the field near the railroad. These wells derived their oil from sands, and do not reach any porous limestone. By these operations the daily production of the field, which had fallen to 4,500 barrels, was considerably raised. In the autumn of 1905 the production fell to less than 4,000 barrels daily.

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[a] Bull. U. S. Geol. Survey No. 212, p. 170.

[b] Mr. Holland S. Reavis, editor of the Oil Investors' Journal.

CHARACTER OF THE OIL.[a]

The gravity of average Spindletop oil is 21.9° B. On refining it yields:

Refined product of average Spindletop oil.	Per cent.
Gasoline	1. 8
Kerosene	17. 1
Solar	15. 4
Lubricating	52. 2
Asphalt	7. 5

SOUR LAKE FIELD.

The Sour Lake oil field is in Hardin County, about 20 miles west by north from Beaumont. It is reached by the newly constructed Beaumont, Sour Lake and Western Railroad; also by an 8-mile branch of the Southern Pacific, which leaves the main line at Nome. The place takes its name from a pond fed by springs and wells of highly mineralized water which is believed to possess medicinal properties. A hotel was constructed some years ago, and the place is well known as a resort.

SURFACE INDICATIONS AND HISTORY.

FIRST OBSERVED EVIDENCE OF OIL.

The surface indications which led to drilling for oil at this place are various. In the vicinity of the lake occasional seepages of oil and bubbles of gas have been noted since the earliest settlement. At places near the lake a black asphaltic substance has also been observed, strongly impregnating the soil, forming a kind of crust or even coating the surface.[b] This substance is believed to be a residuum left by the evaporation of petroleum. Sulphur is also said to be found in the soil, but it is not known that this was considered significant before the actual discovery of the oil. Like the sour waters of the springs and lake, sulphur has subsequently received some attention as an associate of oil in the Coastal Plain, on account of its very frequent occurrence in the oil fields.

EARLY EXPLOITATION.

Drilling at Sour Lake began in 1893. In 1895 Savage Brothers found oil in several shallow wells. Various projects held attention on the matter until, in 1898, the Gulf Coast Refining Company built a refinery with a capacity of 100 barrels of oil daily. By this time no less than five wells had been drilled, none of them exceeding 280 feet in depth. Three of them, drilled by Savage Brothers, found oil at about 230 feet. This was a dark oil, with a gravity of about 16° B. and suitable for lubricants, which it was the intention of the Gulf Coast Refining Company to manufacture. Savage Brothers entered into a contract to supply 100 barrels of crude oil daily, but this was soon found to be impossible and the refinery was closed.

Up to 1901 the prospective field at Sour Lake was similar to that at Nacogdoches in the character and depth of its oil, as also in industrial conditions.[c] It differed only in the age of the formation in which the oil occurred. The area prospected was in the southern half of the present developed field and extended eastward from the lake.

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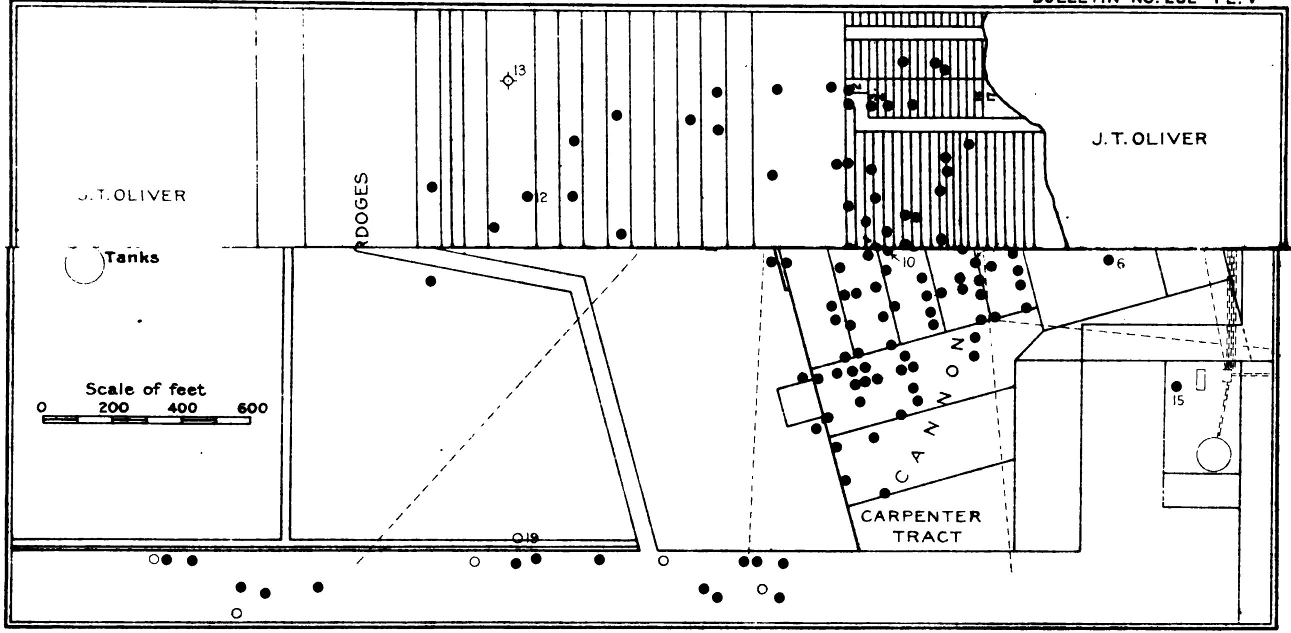
[a] Information received from Mr. J. S. McNamara, of the United Oil and Refining Company, Beaumont, Tex.

[b] The first published account of these features is in Wall's work on the asphalt deposits of Trinidad.

[c] Compare also the Saratoga field, p. 57, and the Jennings field, p. 100.



MAP OF SOUR LAKE OIL FIELD.

THE NORRIS PETERS CO., WASHINGTON, D. C.

Deep drilling began in 1901. In the summer of that year the Guffey well No. 1, on the extreme west side of the field, was sunk to a depth of 1,200 feet. A sputtering of gas, mud, and sand, with some oil, was noted at 900 feet. Similar indications were obtained in the Great Western well, in the Rodgers tract near the railroad. It was drilled to 1,500 feet in November of the same year. This well is also noteworthy for the large amount of hot water encountered (see p. 120). In March, 1902, the Great Western Company obtained a natural flow or gushing of oil in a well 683 feet deep, located some 500 feet south of the Wirt Davis tract. The experience of this well showed the necessity of a strainer (an invention not yet perfected) to prevent loose sand from entering and choking the well.

BEGINNING OF PRODUCTION.

The first genuine success was the W. B. Sharp well, drilled in January, 1903, in the Wirt Davis tract. The facts concerning this well were for a time kept secret. The Texas Company also obtained flows from two wells on the large tract belonging to the Sour Lake Springs Company, but the facts were not then made public. In May came the Gilbert No. 1, a famous gusher, yielding 15,000 to 20,000 barrels per day. This became the signal for immediate drilling by a host of operators. "By August 1, 1903, 220 wells had been completed, or were in the process of drilling, and the output of the field exceeded 100,000 barrels a day."[e] Many of these early wells were in the best part of the field, in and near the south end of the Wirt Davis tract, and had an initial yield of more than 10,000 barrels daily. Only a small minority yielded less than 1,000 barrels. Before the close of the year the field had produced more than 8,000,000 barrels.

TOPOGRAPHY.

Some effort has been expended in instrumental surveys to show the existence of a mound at Sour Lake similar to that of the Beaumont field. The necessity of measurements indicates at once the fact that any elevation in this field is of a very different form from that of Spindletop. Levelings show a difference of 20 feet between the highest part of the field and the lowest part of the salt marsh on the southeast. The relief within the field itself amounts to at least 10 feet. The inequalities are, however, highly irregular, and there is no well-defined mound.

The differences of elevation are due to three causes: (1) Unequal settling of the sedimentary formations, (2) erosion, and (3) the activity of the same uplifting agencies which made the mounds of the Coastal Plain. There is a possibility of a fourth factor, namely, settling due to the dissolving of salt deposits, but this can not be demonstrated. The phenomenon of unequal settling of unconsolidated sediments is sufficiently common on the Coastal Plain to need no further mention.

The beginnings of erosion at Sour Lake are evident. Pine Island Bayou, several miles to the south, follows near the edge of the Beaumont clays as mapped by Kennedy. On its southern side this stream is practically without tributaries. On its northern side tributaries have begun to incise the sandier terrane which has been regarded as of Columbia age. The progress of stream dissection is more marked farther north, but its beginnings are noted at Sour Lake.

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[e] Reavis, Holland S., The Texas Almanac, 1904, p. 159.

GEOLOGIC FORMATIONS.

WELL SECTIONS.

The following logs illustrate the character of the geologic formations at Sour Lake. Complete logs were not obtained of wells which entered porous limestone, gypsum, or salt:

Logs of wells in Sour Lake field.

HIGGINS NO. 8.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Blue and yellow mud	20	20
2	White sand	20	40
3	Blue mud	20	60
4	White sand	20	80
5	Blue mud	20	100
6	White sand	20	120
7	Blue mud	50	170
8	Blue sand	110	280
9	Blue mud	30	310
10	White sand	30	340
11	White rock	1	341
12	Blue mud	9	350
13	White sand	60	410
14	Blue mud	10	420
15	White rock	1	421
16	White sand	10	431
17	Blue mud	20	451
18	White rock	1	452
19	White sand	13	465
20	Blue mud	75	540
21	White rock	2	542
22	Blue mud	8	550
23	White rock	2	552
24	Blue mud	8	560
25	Oil and water sand	25	585
26	Blue mud	30	615
27	White sand	40	655
28	Blue mud	80	735
29	White rock	2	737
30	Blue mud	58	795
31	White rock	1	796
32	Blue mud	29	825
33	White rock	1	826
34	White sand	29	855
35	White rock	2	857
36	Blue mud	68	925
37	White rock	2	927
38	Blue mud	100	1,027
39	White rock	1	1,028
40	Blue mud	7	1,035
41	White rock	1	1,036
42	Blue mud	17	1,053
43	White rock	22	1,075
44	Blue mud	3	1,078
45	White rock	1	1,079
46	Blue mud	11	1,090
47	White rock	1	1,091
48	Blue mud	9	1,100
49	White rock	1	1,101
50	Blue mud	4	1,105
51	White rock	1	1,106
52	Blue mud	6	1,112
53	White rock	2	1,114
54	Blue mud	3	1,117
55	White rock	1	1,118
56	Blue mud	15	1,133
57	White rock	1	1,134
58	Blue mud	26	1,160
59	White rock	1	1,161
60	Blue mud	9	1,170
61	White rock	1	1,171
62	Blue mud	3	1,174
63	White rock	1	1,175
64	Blue mud	50	1,225
65	White rock	5	1,230
66	Blue mud	25	1,255
67	White rock	5	1,260
68	Blue mud	15	1,275
69	Rock honeycomb?	15	1,290
70	Blue mud	10	1,300
71	White rock	2	1,302
72	Brown shale	58	1,360
73	Red gravel	2	1,362
74	Blue mud	16	1,378
75	White rock	1	1,379
76	Blue shale	101	1,480
77	Blue mud	45	1,525
78	White rock	1	1,526
79	Blue mud	9	1,535
80	White rock	1	1,536
81	Blue mud	22	1,558
82	White rock	1	1,559
83	Blue mud	31	1,590
84	White rock	1	1,591
85	Blue mud	13	1,604
86	White rock	1	1,605
87	Blue mud	2	1,607
88	White rock	1	1,608
89	Blue mud	4	1,612

GUFFEY NO. 4.

[McKallip Brothers, drillers.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Surface clay	20	20
2	White sand	20	40
3	Gumbo	20	60
4	Sand	10	70
5	Gumbo	39	109
6	Sand	10	119
7	Gumbo	14	133
8	Sand	126	259
9	Gumbo	43	302
10	Sand	42	344
11	Shell rock	1	345
12	Gumbo	3	348
13	Shell rock	1	349
14	Gumbo	20	369
15	Sand	13	382
16	Hard sand	22	404
17	Gumbo	19	423
18	Shell rock	3	426
19	Gumbo	77	503
20	Shell rock	1	504
21	Gumbo	25	529
22	Sand	17	546
23	Gumbo	5	551
24	Sand	23	574
25	Tough gumbo	11	585
26	Shell rock. A 6-inch pipe was remeasured and 10-inch pipe set on the above-named shell rock, the depth being measured at 595 feet	1	586
27	Gumbo	38	633
28	Sand showing oil	5	638
29	Hard rock	1	639
30	Gumbo	18	657
31	Shell rock	1	658
32	Yellow clay	10	668
33	Limestone and sand rock mixed	6	674
34	Red clay	35	709
35	Hard shell rock	1	710
36	Gumbo	8	718
37	Shell rock	2	720
38	Gumbo	17	737
39	Limestone and iron pyrite	2	739
40	Sand with small showing of oil	45	784
41	Shell rock	2	786
42	Gumbo	9	795
43	Sand, fairly hard; small showing of oil	27	822
44	Rock	2	824
45	Gumbo	13	837
46	Red clay	19	856
47	Gumbo	21	877
48	Rock with thin strata of gumbo	7	884
49	Rock	5	889
50	Gumbo	30	919
51	Hard rock	3	922
52	Gumbo with thin strata of rock	25	947
53	Gumbo	42	989
54	Rock	1	990
55	Gumbo	17	1,007
56	Oil sand with good showing	18	1,025
57	Black gumbo	5	1,030
58	Blue shale with strata of rock	11	1,041
59	Blue shale	46	1,087
60	Hard blue shale[a]	48	1,135
61	Blue shale	19	1,154
62	Gumbo	4	1,158
63	Rock	2	1,160
64	Blue shale	25	1,185
65	Lime rock	2	1,187
66	Gumbo	63	1,250
67	Iron pyrite	2	1,252
68	Gumbo	24	1,276
69	Iron pyrite	2	1,278
70	Gumbo[a]	26	1,304

[a] At 1,135 feet a blow-out lasted six hours, breaking the 4-inch drill pipe and leaving some 8-inch pipe in the bottom of the well. It was necessary to side track in order to drill deeper.

The following treatment of the geology of the field is based upon data from a large number of wells. Those mentioned specifically are here listed:

Sour Lake wells referred to in the text.

[The numbers at the left correspond to those on the map (Pl. V, p. 38).]

1. Beatty No. 1.
2. Buffalo.
3. Gilbert No. 1.
4. Gilbert No. 2.
5. Gilbert No. 4
6. Great Western.
7. Guffey No. 3.
8. Guffey No. 4.
9. Guffey No. 5.
10. Hamill.
11. Higgins No. 6.
12. Higgins No. 7.
13. Higgins No. 8.
14. Sharpe No. 1.
15. Sour Lake No. 1.
16. Texas No. 11.
17. Texas No. 15.
18. Texas No. 20.
19. Texas No. 34.

COASTAL PLAIN SEDIMENTS.

As noted above, Kennedy's geologic map places the Sour Lake field on the outcrop of the Columbia (Pleistocene) sands. The delimitation of these from the Beaumont clays is primarily by fossils rather than by the nature of the sediments. Nevertheless, it may be noted that from Sour Lake northward the soil becomes progressively more sandy.

The beds, for the first 700 feet or more of depth, are clays, sands, gravels, and limestones, no one of which has a constant position in the column. Any one horizon may be represented at one place by a sand, and a hundred feet away by a limestone or clay. In some places the deposits may be of lens-like form; in others the nature of the bed may change without change of thickness. In any case the log of one well affords no suggestion of what may be found in another a few hundred feet away.

Of a large number of well records from this field, only a few show the character of the beds in the upper third or half of the section. Where these are given, the records do not indicate such a distinct dominance of sand in the first 400 or 500 feet as was found at Spindletop. It is true in a general way that sands are more abundant to that depth than lower, but it is also true that below 400 feet the Sour Lake logs do not generally show the long unbroken stretches of gumbo which are characteristic of the Beaumont wells. From 400 to 1,000 feet sands are frequently interspersed in the clays.

In the well sections whose upper parts are recorded, the proportions of sand are given in the following table. In the entire section of the Hill well, 1,780 feet deep, very little is reported besides sand.[a]

Proportion of sands in surface beds at Sour Lake.

Well.	Thickness of sand.	In the first—
	Feet.	*Feet.*
Higgins No. 6	233	358
Higgins No. 7	255	380
Higgins No. 8	260	410
Guffey No. 4	140	404
Texas No. 34	71	339

Beds of limestone from a few inches to a very few feet thick are of frequent occurrence, some wells showing as many as twenty such within 1,000 feet.

POROUS LIMESTONE.

Beneath the generally unconsolidated formations of the Coastal Plain there is, in at least a small part of the Sour Lake field, a crystalline or cavernous limestone of the true Spindletop type (see p. 26). The area in which such rock is definitely known is a strip about 700 feet east and west by about 250 feet north and south. This strip covers the southern part of the Wirt Davis tract, extending west into the Gilbert tract, and east into the J. M. Guffey Petroleum Company's lease. On its southern side this strip includes some of the wells of the Texas Company in the Sour Lake Springs tract. About half a mile directly south of this area, somewhat centrally located in the Cannon tract, a well drilled by James Hamill penetrated a similar porous limestone to a depth of 12 or 15 feet, finishing at 1,091 feet and deriving its oil from this rock. A few other wells in the Cannon tract seem to have finished in this rock and to have derived their oil from it, but most of the reports of such occurrences in this part of the field are believed to refer to wells which derive their oil from beneath rather than from within the limestone. Most of the wells in this part of the field are shallower than the Hamill well, and while passing through some limestone, it seems to be generally true that it is of the dense kind referred to above as occurring in the sediments above the porous limestone. A considerable number of these wells are familiarly spoken of as "rock wells." The fact that many of the wells in and near the Cannon and Rodgers tracts have been greatly troubled with sand and are obliged to use strainers indicates that they should be classed with the sand wells and not with those which derive their oil from the porous limestone.

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[a] It is to be remembered that drillers differ in the naming of materials as well as in the care with which the records are kept.

FORMATION BELOW THE LIMESTONE.

The immediate lower neighbor of the limestone is not well known. On the northern edge of the area outlined above as being underlain by porous limestone, oil is reported as being obtained from sand beneath the limestone, the latter in this case being dense. White sand having a thickness of 60 feet is said to underlie the limestone in the Gilbert tract. Samples were not seen, but as this so-called sand was said to be entirely lacking in grit and to come out in small chunks which could be crushed between the fingers, it may be a material not unlike that which was found beneath the limestone at Spindletop and which seems to be a marl rather than a sand. In the Gilbert No. 2, gumbo intervenes between the limestone and the so-called white sand. A short distance to the east, in the Wirt Davis tract, the same relations exist.

GYPSUM.

In the Texas well No. 11, 16 feet of gypsum are reported as encountered at a depth of 1,180 feet. This was immediately below 14 feet of limestone which were reported as "oil rock." Inasmuch, however, as this well is classed as a "dead gas well" and has not produced oil, the nature of the rock is uncertain. If, whatever be its character, it represents the horizon of the porous oil rock, the gypsum reported is in the same general position with reference to the porous limestone as that in which it is found in the Beaumont field, the one difference being that between the oil limestone and the gypsum at Beaumont a bed of marl, clay, or sand commonly intervenes.

ROCK SALT.

Not less than ten wells within the area underlain by the porous, oil-bearing limestone are reported as having penetrated rock salt. The farthest west of these is the Gilbert No. 4. In it the salt was found separated from the oil-bearing limestone by a bed of hard clay or shale. In strip No. 5, 150 feet farther east, where the top of the limestone is at a depth of 800 feet, salt was encountered at a depth of 885 feet. The drill penetrated the salt 10 feet and stopped there, leaving the thickness of the formation unknown. The Buffalo well, in strip No. 11, 300 feet east of the Gilbert No. 4, stopped in salt at a depth of 1,090 feet.

PYRITE.

Iron pyrite is found at almost all depths, both above and below the oil. So far as noted, this substance is most abundant at or below the horizon of the oil. It was conspicuous below this depth in well No. 1 of the Sour Lake Oil Company and at a depth of 1,400 to 1,500 feet in the Great Western well. In the latter case clay from 5 to 10 feet thick, strongly impregnated with pyrite, alternated with other clay beds from which pryite was absent. A careful foreman (Mr. Black, of the Higgins Oil and Fuel Company), whose work has been with those wells in which the oil is derived from the sand, states that pyrite is always found in the rock just above the oil and to some extent in every consolidated rock below 340 feet.

STRUCTURE.

SEDIMENTARY FORMATIONS.

The determination of geologic structure from well borings alone necessarily implies that a given bed is recognizable and traceable from well to well. On account of the marked lack of lateral continuity in these Coastal Plain deposits, this is for the most part impossible. No significance can be attached to the varying depths at which oil is found in a group of sand wells, except as an illustration of the limited area of any one sand and of the irregular depths at which sands occur. (See fig. 12, p. 119.) The determination of dips by such evidence is of no value whatever.

STRUCTURE INDICATED BY THE POROUS LIMESTONE.

Within that small part of the field where the oil-bearing limestone has been exploited the case is somewhat different. The limestone is recognizable with a fair degree of certainty, and wells are so near together as to reduce the chances of error to a minimum.

The oil limestone, so far as recognized in and near the Wirt Davis tract, has a northeasterly, though by no means uniform, dip. It is nearest the surface in the Gilbert wells, where it is encountered at a depth of 660 feet, and is from 20 to 25 feet thick. The inclination of its upper surface in strip No. 1 (the strips of the Wirt Davis tract being numbered from west to east) is nearly 45° N. One hundred and fifty feet farther east the rock is found at a depth of 780 feet. It is reported here to be 100 feet thick. A few rods north of this latter point its depth is 800 feet. In the Texas well No. 20, south of the road, a formation is reported at 754 feet, which may represent the same rock, indicating a continued rise to the south, but no wells farther south in this locality encounter the rock. Near the small stream a few hundred feet farther east the depth of the rock is from 830 to 840 feet, and its southern edge appears to be near the southern border of the Wirt Davis tract. Still farther east the Guffey well No. 5 reached the rock at a depth of 881 feet and penetrated to a depth of 22 feet without passing through to ascertain its thickness. At this point it appears that the rock is present south of the road in the Texas No. 15 and is found at a shallower depth. The Guffey well No. 3, 150 feet still farther east, was drilled to a depth of 1,117 feet, but no rock was encountered.

The oil-bearing limestone of this part of the Sour Lake field has its highest point near the southeast corner of the Gilbert tract. From this point it dips to the north and east but is not found to the south or west. Northward from this highest point the rock extends about 200 feet, and eastward it extends 600 feet. The highest point is 660 feet below the surface. The margin on the north side is 800 feet deep, and on the east side 881 feet. The extreme height of the structure, so far as it is known, is therefore 221 feet. These figures are similar to the corresponding figures taken from Spindletop. It may be necessary to state once more that these figures may or may not represent actual local dips of beds. They indicate the depth of the upper surface of a body which is not sedimentary and which may have any position with reference to bedding planes (see p. 45).

The known occurrences of the porous limestone in the Cannon tract are too few to be used in the determination of structure. If inferences may be drawn from the depths of the many wells which have derived their oil from beneath a limestone, it may fairly be concluded that there is in this part of the field a gentle dip to the south and the east. Some much deeper wells on the west and northwest side of the field reach no porous limestone.

INFERENCES.

In accordance with the facts summarized below it is believed that the strata underlying the area are approximately horizontal. This does not apply to the crystalline, porous, oil-bearing limestone, whose form is not believed to be that of a sedimentary bed. The indications which seem to exclude steep dips from the sediments may be summarized as follows:

(1) The horizon of the oil differs but a few hundred feet in long distances, and when it is remembered that four or five petroliferous sands are often passed in the same well even this difference of depth loses all significance as to dips, because of the impossibility of correlating the sands of different wells. What is true of the petroliferous zone as a whole is true of the more restricted oil-bearing horizons, some of which seem to have a certain continuity throughout limited portions of the field.

(2) There is no evidence whatever of dips from the surface outcrops. The character of the beds at the surface in the oil field is essentially that of the surface beds in the surrounding region.

NATURE OF THE LIMESTONE.

The characteristic features of the porous limestone are those of a precipitate of calcite (sometimes dolomitic) from ground waters. At places the entire mass of limestone is of this origin. At other places there has been only enough solution and precipitation to cement a calcareous bed into a dense, hard limestone. Between these extremes there are all gradations, representing all possible proportions of original calcareous sediment and of crystalline calcite. There are also gradations between pure sand and both of the extremes named above.

So far as the limestones found at Sour Lake are due to the consolidation or cementation of calcareous beds they are generally thin plates, dense and hard. These are of the most common occurrence and are believed to be nearly horizontal, occurring at any and all depths and being of very limited lateral extent. Thicker layers of this kind have, in various parts of the field, formed impervious covers over oil-bearing sands, and therefore constitute true cap rocks. Such a rock may, however, be locally crystalline and cavernous, due to the local activity of ground waters. In such a case the rock itself may bear the oil instead of acting as a cap to confine it in the lower sands. This is without doubt the case in the Cannon tract, where a limited number of wells derived oil from the limestone. These local masses of porous limestone may belong to the horizon of the dense limestone which, in other wells, serves as cap rock, or they may be separate bodies.

So far as the limestone is a precipitate from water, its surface may show almost any form. Though influenced to some extent by the bedding, it may be expected to exemplify all the freakishness of concretions. Horizontality, or the lack of it, must not, therefore, be taken too seriously or ascribed to causes too profound. In entire harmony with this, it may be stated as a general principle based on observation, that steep dips in the oil-bearing mounds are limited to the limestones (or dolomites) which have been precipitated from water. The dense, hard plates due to cementation are, so far as known, nearly or quite horizontal. This statement does not apply to the higher mounds which have not as yet produced oil.

OCCURRENCE OF THE OIL.

CLASSIFICATION OF WELLS.

By the different relations of the oil to the rock, the Sour Lake wells fall naturally into three classes: (1) Those which derive their oil from the pores and caverns of the limestone, (2) those in which the oil is found beneath a limestone cap rock, (3) those which find oil in beds of sand, confined by clays, and in which limestone, if occurring at all, bears no relation to the oil reservoir. There is no essential distinction between wells of the last two types. The three classes are differentiated here because wells of the second class are frequently spoken of as "rock wells" and confused with wells of the first class.

WELLS IN THE LIMESTONE.

Probably wherever the porous limestone has been encountered in this field, it has yielded oil. While a relatively small portion of the field affords this source of oil, the wells of this small area have yielded the larger part of the product. In both the rate and duration of their production they have been superior to the wells which have tapped the sands only. In the Gilbert and Wirt Davis tracts alone about 150 wells have been drilled, most of them in the limestone, many of these yielding at the start more than 10,000 barrels daily. "The Sharp well produced 325,000 barrels in twenty days, valued at $80,000; Gilbert No. 1 produced enough petroleum in thirty days to bring $125,000" (Oliphant). It is noteworthy, however, that several of the sand wells drilled later on the northwest side yielded, under compressed air, 3,000 to 5,000 barrels daily, but this rate was continued for only a short time.

WELLS IN THE SAND.

The so-called "rock wells" of the second class are frequent in the central and southern parts of the field. In the larger part of the field, including the whole of the "Shoestring district," the oil is found in reservoirs of sand, overlain by impervious clays. Wells of the second and third classes find oil at almost all depths from the heavy oil at 230 feet to the large quantities of a better grade found between 1,300 and 1,400 feet on the northwest side of the field. All mention of "first sand," "second sand," "third sand," etc., is misleading. The most that can be said is that certain broad and poorly defined horizons are richer than others in oil-bearing lenses or patches. The deeper wells afford some suggestion of a definite oil-bearing stratum, but the area thus characterized is small, and the oil should be spoken of as belonging to a horizon which may be defined within certain limits, rather than to a definite bed.

It is not now possible to say to what extent the areas affording sand wells are underlain by an oil-bearing limestone and the oil in the sands supplied by upward leakage from the limestone. It is not definitely known that such relations exist, but the showings of oil in the sands directly over the oil-bearing porous limestone in this and other fields offer a strong suggestion of such a relation. It can not be affirmed, however, that this relation is general, because prolific oil sands have been found, both at Spindletop and Sour Lake, at lower levels than that of any known limestone. Thus far, also, no oil-bearing or porous limestone has been found at Saratoga or Jennings.

SALT WATER.

All except the surface waters within the field contain some salt. Water from depths greater than 100 feet is rarely fresh enough for drinking or for use in boilers. At the depths where wells are finished the water may be intensely briny.

REGULAR ADVANCE.

In its relations to the oil, the salt water at places behaves very much as it does in the Appalachian fields. Considerable areas have shown a progressive invasion of salt water, advancing from well to well, beginning with those which found the oil at greater depths and proceeding up the dip of the oil-bearing rock to the shallower wells. This mode of invasion is typically illustrated in the limestone wells of the Wirt Davis tract. In August, 1893, salt water appeared in the eastern member of this group and began its advance westward. More than a year later there was still left a gradually diminishing group of limestone wells which were free from salt water and were yielding the greater part of the product of the fields. By the close of 1904 only three wells in this group were producing oil without salt water.

IRREGULAR ADVANCE.

Other parts of the field do not afford examples of this well-recognized relation between oil and salt water. It must be accepted as a general principle that where oil and salt water are contained in the same reservoir the latter will buoy the former up, and on the exhaustion of the oil the water will follow it into the well. However, where porous sands, impervious clays, and porous limestones with impervious crusts have such an apparently lawless distribution as in these Coastal Plain sediments, either oil or water may be contained in a practically sealed reservoir or the communication between the two may be of any degree of freedom. Some wells therefore "go dry," or, to speak more accurately, the oil when exhausted is followed by insignificant quantities of water, which enters the formation from which the oil has been removed, but with exceeding slowness, because to do so it must traverse the clays. At other places the advance of the salt water across the field is by the most devious and apparently haphazard course, some wells producing oil without water for weeks or even months after their neighbors on all sides have gone to water. Again, the salt water may appear suddenly in the most unexpected place.

These irregularities are well illustrated on the west side of the group of limestone wells in the Gilbert and Wirt Davis tracts. It is commonly said that the wells on the east side of the group go to salt water and those on the west side to gas. The only significance of this latter expression is that the gas so abundantly associated with the oil of the rock wells continues to exhale slowly from the porous rock after the quantity of oil capable of being pumped has become very small.

In November, 1904, the Landry wells were conspicuous for their freedom from salt water, while the surrounding wells were yielding gradually increasing quantities. Such has been the case with an occasional well in the Cannon tract. In September, 1904, the original "Beatty gusher" was still yielding oil without water, while some of its neighbors had gone dry and others were yielding mainly water. In a general way, however, the salt water has invaded the Cannon tract as it did the Wirt Davis tract, from the east.

HOT WATER.

There are various reports of "hot water," but the data concerning the taking of the temperatures are not obtainable. The Higgins well No. 4 is said to have encountered water at 101° F. at a depth of 985 feet. This water was intensely salt. The Great Western reported water at 100° F. from a depth of 850 to 880 feet. These reports were made while drilling, and the water was obliged to rise to the surface on the outside of the pipe. It is therefore to be supposed that some heat was lost in the ascent.

GAS.

The amount of gas released in this field has been very great. Strong gushers were obtained in various parts of the field and flowing wells were common. The gas is similar to that at Spindletop. That which comes from the porous limestone is equally poisonous and, as noted above, continues to exhale from wells where salt water has failed to appear when the oil has been practically exhausted.

PRODUCTION.

NUMBER OF WELLS.

Up to August 15, 1904, 467 wells had been finished and 15 were drilling; 181 had been abandoned, 32 were reported dry, and 254 were producing intermittently, though the average number in daily operation was about 105.[a] These figures apply to all wells within a radius of 5 miles, but the number of wells more than one-half mile from the center of the field is very small. The activity in the second half of 1904 was somewhat greater than in the first half.

QUANTITY OF OIL.

During its first year (1903) the field produced 8,700,000 barrels. The maximum rate was in August and September, when the average daily production ranged from 50,000 to 60,000 barrels. For short periods the yield exceeded 100,000 barrels daily. From that time the production steadily declined until, in July, 1904, it was but 11,000 barrels. About that time, however, the decline at Batson redirected attention to the staying qualities of the Sour Lake field and there was a revival of successful development, the result being an intermittent rise of the daily output to 19,000 barrels in December, 1904. The chief gain in the latter half of 1904 was from deep sand walls (1,300 to 1,400 feet) on the west and northwest sides of the field. Early in 1905 the entire group of these deep sand wells went to salt water. The statistics compiled by Mr. Oliphant[b] give 6,442,357 barrels for the yield of 1904, or more than 2,000,000 barrels less than that of the former year. In October, 1905, the daily production slightly exceeded 7,000 barrels.

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[a] Oil Investors' Journal, September 15, 1904.

[b] Mineral Resources U. S., 1904.

CHARACTER OF THE OIL.

Taken as a whole the Sour Lake crude oil is practically identical with the Beaumont. Its gravity averages about 22 B°. On refining, it yields less than 2 per cent gasoline, 17 per cent kerosene, 15 to 16 per cent solar, and fully 52 per cent lubricating oil.[a] The shallow oils discovered before 1902 have a gravity of 16° to 18° B. The deepest oil (1,300 to 1,400 feet) is said to have a gravity of 24.7° B.

BATSON FIELD.

HISTORY.

Next to Spindletop, Batson has the most sensational history of any oil field on the Coastal Plain. This is due largely to its discovery at a time when the rapid decline of the Beaumont field and the waning production of Sour Lake set free a large number of men and drills. It is also due in part to the rare chance by which the first well pierced almost the center of the field. The wells were, therefore, from the start, phenomenally successful. The drilling in this field is also easy and is comparatively free from certain disadvantages, such as caving, which attended the drilling at Spindletop. The discovery of the Batson field came at a time when the Santa Fe Railroad had but recently built a branch to Saratoga, thus giving a railroad station within less than 6 miles from the new field.

Surface indications inviting drilling in this vicinity were never abundant. Bubbles of gas may be seen rising from pools of water, but whatever seepage of oil there may have been is now obscured by the abundant waste from the wells.

In 1901 the Libby Oil Company drilled a well 3 miles to the south, but, with the exception of a slight showing of oil at about 1,000 feet, this trial offered but little encouragement. The second attempt was by the newly organized Paraffine Oil Company, of Beaumont, which, on October 31, 1903, found oil at a depth of 790 feet not far from the center of the Batson field. This well became a good producer. On December 19 the same company brought in its second well, which, after a little preliminary difficulty with sand, yielded by natural flow 4,500 barrels of oil per day.

The effect of these successes was such that by the close of the year 1903 there were 28 derricks in the new field, many of them representing partially completed wells. The two Paraffine wells were followed early in January by the Brooks No. 1, of the J. M. Guffey Petroleum Company, a vigorous gusher with an initial daily production of 18,000 barrels. Development work was so rapid that, on March 4, the daily production of the field had reached 151,000 barrels. At this time salt water, which had been noticeable from the start, began to make rapid advance, and by April the production of the field had fallen to 35,000 barrels a day. The larger part of the total production of the field to the close of 1905 was in the first half of the year 1904.

LOCATION AND TOPOGRAPHY.

The site of this field is Batson Prairie, a mile or more distant from the village and post-office of Batson, Hardin County. The field is 7 miles southwest of the village of Saratoga and less than 6 miles from Saratoga station. It is 13½ miles west by north from Sour Lake. The distance from the Gulf coast is 45 miles. The coastal prairie at this distance from the Gulf alternates with woodland, which for the most part follows the streams.

Batson Prairie is a comparatively flat stretch of ground lying between the southeastward-flowing tributaries of Pine Island Bayou. The relief due to the faint stream cutting is perhaps 10 feet. While apparently flat, it is probable that the elevation of the oil field is slightly greater than that of the surrounding forest. There is no superficial suggestion of a mound of the Spindletop type.

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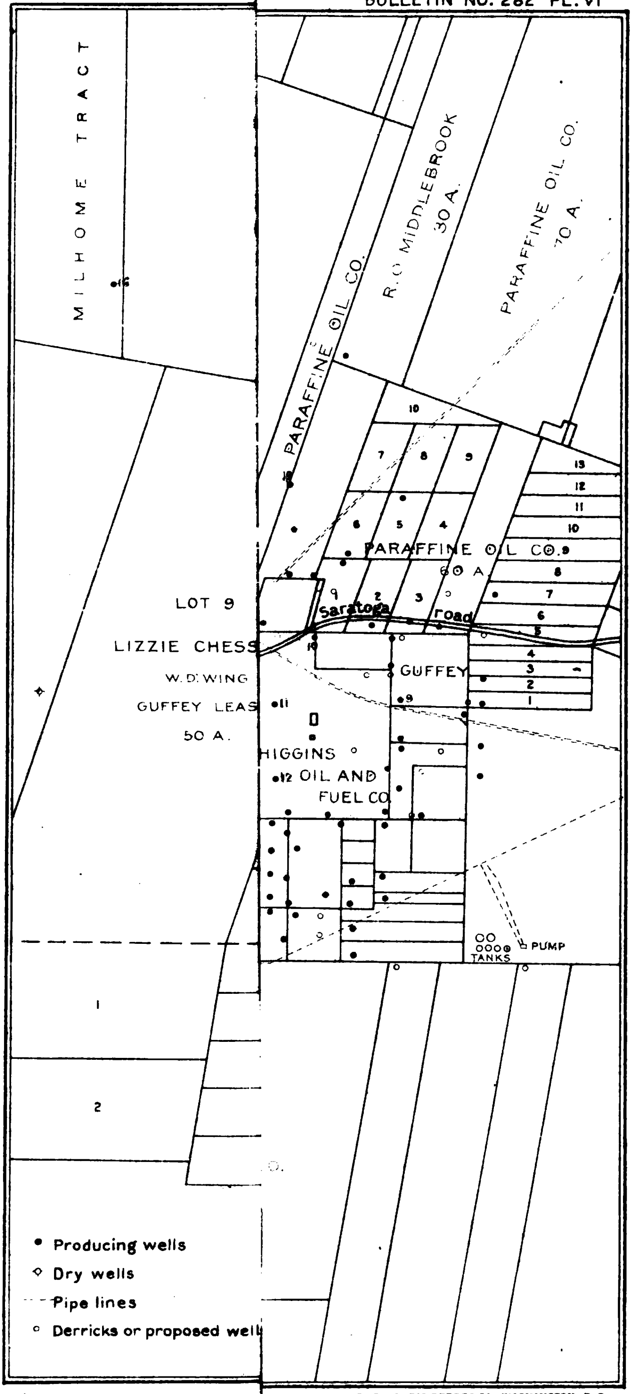
[a] Information received from Mr. J. S. McNamara, of the United Oil and Refining Company, Beaumont, Tex.



THE NORRIS PETERS CO., WASHINGTON, D. C.

LIMITS OF THE FIELD

Before the spring of 1905 the oil-producing area had been outlined with a considerable degree of exactness and was surrounded by dry holes. New work in the winter of 1904–5 was confined to the west side of the field, chiefly to the Wing and Milhome tracts. In the month of January, 1905, but four new wells were being drilled and four old ones being deepened. At about that time the successful development of the Milhome tract, on the extreme west side of the field, caused a revival of operations and a consequent increase of production The productive area of the field, as outlined in the spring of 1905, did not exceed 400 acres. Its shape gives no suggestion of axial directions.

GEOLOGIC FORMATIONS.

WELL SECTIONS.

The following logs are typical of the Batson field:

Logs of wells in Batson field.

HIGGINS OIL AND FUEL COMPANY, NO. 4.

[Finished May, 1904.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Mud and sand	325	325
2	Oil sand and shale	5	330
3	Blue shale	85	415
4	Oil sand and shale	15	430
5	Blue shale	190	620
6	Oil sand and shale	15	635
7	Shale	195	830
8	Rock and sand	40	870
9	Shale	30	900
10	Rock	1	901
11	Blue mud	54	955
12	Oil sand and shale	10	965
13	White mud	5	970
14	Oil sand and rock; salt water, 80° F	15	985
15	Blue shale	70	1,055
16	White rock	1	1,056
17	Blue shale	9	1,065
18	White rock	1	1,066
19	Oil sand and shale	15	1,081
20	Blue mud	19	1,100
21	Oil sand and shale	25	1,125
22	White rock	3	1,128
23	Oil sand and shale	2	1,130
24	White rock	2	1,132
25	Hard shale	10	1,142
26	White rock	2	1,144
27	Blue shale	2	1,146
28	White rock	1	1,147
29	Blue shale	3	1,150
30	White rock	1	1,151
31	Blue shale	7	1,158
32	White rock [a]	1	1,159

J. M. GUFFEY PETROLEUM COMPANY (STATE LAND) NO. 14.

1	Clay	45	45
2	Sand	55	100
3	Gumbo	90	190
4	Rock	15	205
5	Gumbo	65	270
6	....do	35	305
7	Blue shale	20	325
8	Gumbo	45	370
9	Blue shale	21	391
10	Gumbo	50	441
11	Rock	2	443
12	Blue shale	20	463
13	Gumbo	16	479
14	....do	3	482
15	Blue shale	18	500
16	Gumbo	18	518
17	Blue shale	30	548
18	Gumbo	13	561
19	Rock	1	562
20	Oil sand	10	572
21	Gumbo	26	598
22	Blue shale	20	618
23	Gumbo	23	641
24	Blue shale	27	668

[a] Pumped 500 barrels at the start. One month later about 400 barrels of oil with 600 of salt water. Salt water from the start at 101° F. A strainer placed wherever oil appears in the log. This is true for all wells at Batson below 475 feet.

Logs of wells in Batson field—Continued.

J. M. GUFFEY PETROLEUM COMPANY (STATE LAND) NO. 14—Continued.

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
25	Gumbo	20	688	44	Gumbo	25	950
26	Oil sand	8	696	45	Shale	10	960
27	Blue shale	16	712	46	Gumbo	30	990
28	Gumbo	18	730	47	Shale	12	1,002
29	Rock	2	732	48	Gumbo	18	1,020
30	Blue shale	13	745	49	Rock	4	1,024
31	Gumbo	10	755	50	Gumbo	11	1,035
32	Rock	20	775	51	Rock	3	1,038
33	Blue shale	25	800	52	Shale	10	1,048
34	Rock	6	806	53	Gumbo	21	1,069
35	Blue shale	14	820	54	Shale	12	1,081
36	Gumbo	10	830	55	Gumbo	10	1,091
37	Oil sand and shale	35	865	56	Rock	6	1,097
38	Rock	3	868	57	Gumbo	21	1,118
39	Gumbo	10	878	58	Shale	7	1,125
40	Rock	2	880	59	Gumbo	17	1,142
41	Shale	11	891	60	Rock	6	1,148
42	Gumbo	24	915	61	Gumbo; rock and slight showing of oil[a]	2	1,150
43	Shale	10	925				

J. M. GUFFEY PETROLEUM COMPANY (WING) NO. 21.

[Completed June 23, 1904.]

1	Red clay	40	40	26	Gumbo	20	650
2	Oil sand	20	60	27	Shale	64	714
3	Shale and gumbo	20	80	28	Shale and oil	25	739
4	Oil sand	10	90	29	Shale	21	760
5	Water sand	50	140	30	Shale and oil	34	794
6	Gumbo	20	160	31	Shale	19	813
7	Oil sand	10	170	32	Gumbo	17	830
8	Hard pan	10	180	33	Sand, soft rock, and gas	44	874
9	Gumbo	20	200	34	Oil, sand, oil rock, and gas	22	896
10	Shale	20	220	35	Shale and gumbo	22	918
11	Gumbo	90	310	36	Oil shale and rock	30	948
12	Shale	58	368	37	Oil sand and rock	13	961
13	Gumbo	22	390	38	Shale and rock	16	977
14	Oil sand	25	415	39	Hard pan	2	979
15	Shale and soft rock	5	420	40	Shale with gas blowout	16	995
16	Hard rock	1	421	41	Sand rock	3	998
17	Shale	30	451	42	Shale	6	1,004
18	Gumbo	51	502	43	Hard sand and rock	20	1,024
19	Shale	25	527	44	Oil rock and shale alternating and containing gas	39	1,063
20	Gumbo	10	537	45	Same with gumbo; no gas	19	1,082
21	Shale	30	567	46	Rock	1	1,083
22	Gumbo	24	591	47	Shale	2½	1,085½
23	Shale	23	614	48	Rock. Water lost and well stopped[b]	1½	1,087
24	Rock	1	615				
25	Shale	15	630				

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[a] Strainers set at 550–575, 680–780, 830–870, 1,090–1,150.

[b] Nine joints of strainer, 180 feet, set at 1,087, above which is one joint of blank pipe, then 60 feet more of strainer. Well still flowing (August, 1904) 225 barrels daily.

Logs of wells in Batson field—Continued.

J. M. GUFFEY PETROLEUM COMPANY (CHOATE) NO. 16.[a]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Clay	50	50
2	Water gravel	40	90
3	Gumbo	30	120
4	Water sand	60	180
5	Shale, oil, and gas	26	206
6	Rock	4	210
7	Gumbo	10	220
8	Rock	3	223
9	Shale	76	299
10	Sand	18	317
11	Rock	3	320
12	Sand	10	330
13	Shale	10	340
14	Rock	5	345
15	Gumbo	25	370
16	Shale	20	390
17	Rock	3	393
18	Gumbo	37	430
19	Shale	20	450
20	Gumbo	15	465
21	Rock	2	467
22	Shale	33	500
23	Gumbo	40	540
24	Slate	50	590
25	Rock	3	593
26	Gumbo	37	630
27	Shale	25	655
28	Gumbo and bowlders	25	680
29	Sand, with slight showing of oil throughout	55	735
30	Slate	45	780
31	Gumbo	20	800
32	Slate	60	860
33	Rock	3	863
34	Slate	37	900
35	Gumbo	110	1,010
36	Shale	35	1,045
37	....do	33	1,078
38	Gumbo	42	1,120
39	Shale	28	1,148
40	Rock	2	1,150
41	Slate and shale	18	1,168
42	Rock	1	1,169

[a] This well has not yet produced; will be deepened.

The data from which the geology of the field is inferred are taken from a large number of wells. Those which are mentioned by name in the text are found in the following list and may be located on the map (Pl. VI):

Batson wells referred to in the text.

[The numbers at the left correspond to those on the map (Pl. VI, p. 48).]

1. Alert.
2. Bates No. 1.
3. Batson Oil Company.
4. Brooks No. 1.
5. Choate No. 1.
6. Choate No. 8.
7. Colorado Syndicate.
8. Douglas No. 5.
9. Guffey (2 acres) No. 1
10. Higgins No. 1.
11. Higgins No. 4.
12. Higgins No. 5.
13. Marshall No. 1.
14. Marshall No. 2.
15. Mary Ellen No. 1.
16. Milhome.
17. Paraffine No. 1.
18. Paraffine No. 2.
19. Paraffine No. 12.
20. Prather & Hughes.
21. Santa Fe No. 1.
22. Santa Fe No. 2.
23. State Land No. 2.
24. State Land No. 14.
25. Wing No. 1.
26. Wing No. 2.
27. Wing No. 4.
28. Wing No. 12.
29. Wing No. 13.
30. Wing No. 19.

SEDIMENTS.

The location of the field on Kennedy's geologic map[a] is on the outcrop of the Columbia (Pleistocene) sands. Not much sand, however, is apparent in the surface soil of the prairie. The proportion of sand increases rapidly toward the north in the vicinity of Saratoga station.

As at Spindletop and Sour Lake, the sedimentary beds traversed in drilling consist of unconsolidated clays and sands with occasional thin beds of limestone. Three or even more of such limestones may be encountered within a thickness of 100 feet. In general they are more abundant in the second 500 feet than in the first. If all the logs received are correct, it appears that such limestones are so irregularly distributed that while some wells encounter 15 or 20 beds, other wells miss them entirely.

The proportion of sands passed is rather smaller than at Spindletop, though perhaps not so strictly limited to the upper beds. In a general way the upper beds, including 100 to 300 feet, are predominantly sand. The proportions found are shown in the following table:

Proportion of sands near the surface at Batson.

Name of well.	Thickness of sand.	In the first—	Name of well.	Thickness of sand.	In the first—
	Feet.	*Feet.*		*Feet.*	*Feet.*
Santa Fe No. 1	213	348	Douglas No. 5 (Guffey)	270	290
Santa Fe No. 2	229	292	State Land No. 14 (Guffey)	55	100
Santa Fe No. 3	132	165	Wing No. 12 (Guffey)	50	100
Texas Co. (Lovett & Davis) No. 12	174	234	Wing No. 19 (Guffey)	310	330
Texas Co. (Higgins Acre) No. 32	150	195	Choate No. 13 (Guffey)	180	220
Higgins No. 5	180	260	Choate No. 16 (Guffey)	100	180
Guffey (2 Acres) No. 1	61	121			

In a well 5 miles northwest of Batson, 1,506 feet deep, only two small water sands were found above a depth of 140 feet, while all below is reported as solid clay.

There is an occasional mention of gravels in the upper sandy layers, but they do not occupy constant positions in the column and must be regarded as isolated patches contained within the sands and clays. The Choate No. 16 reports gravel at from 50 to 90 feet; the Wing No. 19 at from 310 to 330; the Santa Fe No. 3 reports sand and gravel passed through from 145 to 165 feet. In two wells, the Wing No. 1 and Wing No. 4, this gravel, found at a depth of about 200 feet, is said to be highly colored, having pebbles of yellow, red, and black.

POROUS LIMESTONE.

Beneath the sediments here described, and lying at depths varying from a little less than 1,100 to a little more than 1,200 feet, is a rock which is believed to be essentially the same as the porous oil-bearing limestone at Spindletop. This limestone is reported from all parts of the field, and it probably underlies nearly the whole area. Its thickness is determined in two wells near the center of the field as 22 feet in the one case and 30 feet in the other. It is highly probable, however, that both the thickness and the character of the rock are subject to very great variation. The limits of this variation, as described at Sour Lake (see p. 45), will doubtless also hold true for Batson. In brief, it may be said that at places the limestone is a consolidated sediment of close texture, while at others it is crystalline and porous or cavernous and evidently a precipitate from ground waters. Furthermore, it can not be asserted with any degree of certainty that the limestone beds found at approximately the same depth in various parts of the field are connected in one continuous stratum.

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[a] Bull. U. S. Geol. Survey No. 212, 1903, Pl. I.

SULPHUR, PYRITE, GYPSUM, AND SALT.

The abundant reports of sulphur in other fields of the Coastal Plain find no parallel at Batson. It is mentioned in one well only, in the Kiser & Middlebrook tract, where it is said to have been found in a rock locally called "cap rock." What is true of sulphur is to a large degree true of the iron pyrite so abundant in other fields. Pyrite was found with the sulphur in the well mentioned above, and it to some extent impregnates a sandy horizon between 800 and 900 feet deep in the Higgins tract. Outside of these two places it has received very little mention. It is noteworthy, also, that the surface indications noted in other fields as so closely connected with the presence of sulphur are largely absent at Batson. Gypsum is also almost without mention. There is but one mention of salt encountered in drilling at Batson. If the observations of the drillers were correct, 12 feet of salt were found in the Paraffine No. 12, northeast of the center of the field, at a depth of 1,007 feet, or 130 feet above the oil rock. The absence of any other mention of salt leaves this observation open to doubt. It is more probable that the bed in question consists of sand impregnated with salt than of the latter alone.

FORMATION BELOW THE POROUS LIMESTONE.

Because of danger from salt water, very few wells at Batson were drilled through the oil-bearing porous limestone. The Higgins No. 1 passed out of a limestone at 1,222 feet into "a coarse gray salt sand, very porous," 22 feet in thickness. This sand was drilled through with cable tools because of the loss of water in drilling by the rotary process. In one of the Brice & Bradley wells, at 1,190 feet the drill passed through the limestone into "soapstone." It is apparent that very little is known of the formation in the Batson field occupying the same relative position as that of the gypsum, marls, and salt in most of the mounds of the Texas and Louisiana coastal plains (see p. 17). There was at one time a project for the cooperation of several companies in drilling one deep well in the hope of finding a deeper oil than has yet been discovered. Such an attempt, though not promising from an economic standpoint, would be highly interesting in view of the opportunities it might give for comparison of the structures and succession of formations at Batson and elsewhere; for it is highly probable that although there is no superficial mound in this field, the agencies which have been at work are the same as those which have made the Coastal Plain mounds. It is quite possible that the succession of materials at Batson would be found very similar to that at Spindletop, though the proportionate abundance of each might differ greatly.

STRUCTURE.

As in the other fields, the position of the beds is difficult to determine on account of their lateral discontinuity and the resulting impossibility of correlation. The only formation capable of being traced from well to well with any certainty as to its identity is the oil-bearing limestone. It furnishes, therefore, the chief criterion in the determination of structure.

DEPTHS AND DIPS OF THE LIMESTONE.

This formation comes nearest to the surface at the east end of the Marshall lot (Guffey lease). It was encountered here in two wells at depths of 1,081 and 1,088½ feet, respectively. From this place it dips somewhat strongly to the north and east, but a faint ridge or crest of this formation extends in a northeasterly direction through the 12-acre tract of the Paraffine Oil Company to its northeast corner. Along this low crest the depth of the limestone is, for the most part, about 1,136 feet. It dips gently to the south from this crest, reaching a depth of 1,144 feet in the Brooks No. 1, 1,159 feet in the Bates No. 1, and 1,178 feet in the State Land No. 2. The dip to the east and northeast from the end of the crest described is more rapid than that to the south and southeast. In the Choate No. 1, about 500 feet east of where the crest begins to pitch, the depth attained is 1,180 feet. In the Higgins No. 1, 300 feet farther east, it is 1,198 feet. Northward from the assumed crest the depth of the limestone increases but slowly. In the Choate No. 8, on the extreme north side of the field, some 1,700 feet from the crest, the depth is 1,205 feet.

Little is known of the depth or continuity of the limestone west of the highest point in the Marshall tract. There seems, however, to be a separate elevation having its highest point at or near the Wing No. 4, in the southeast corner of the W. D. Wing 100-acre tract. This well found limestone at 1,104 feet, while to the east the Mary Ellen No. 1 and the Wing No. 13 found the same formation at depths of 1,145 and 1,152 feet, respectively. Between this elevation in the Wing tract and the one which culminates in the Marshall tract there is apparently a broad structural depression. It appears that the Wing No. 2, on the west side of the field, encountered a similar rock at a reported depth of 1,136 feet. Whether the elevation thus indicated is connected with either of the other two is open to question.

If the elevation of the limestone indicated at the Wing No. 2 be hypothetically connected with that which appears at the Wing No. 4, there might be some slight presumption that the form of the limestone shows structural lines trending northeast and southwest. This would be somewhat further strengthened by assuming the correctness of the report which ascribes to the same rock a depth of only 1,136 feet in the Paraffine No. 12, east of the Choate tract. This well is almost on a line with the northeasterly extension of the crest described above. It must be admitted, however, that in our present state of knowledge the delineation of the surface of the porous limestone by contour lines is a difficult matter, not free from inconsistencies, and the assigning of any direction to structural lines is no less precarious.

It will be seen from the depths given above that the dips of the oil-bearing limestone are very gentle. Locally, as in the vicinity of the Marshall No. 1, the inclination appears to be as great as 20 feet in 100, but this is altogether exceptional. When one remembers the extreme unevenness of the upper surface of the corresponding formation at Spindletop, such local variations of depth can not be assigned any great structural significance. The next steepest place in the field is probably at the north end of the Guffey State land lease. It would seem that here, between the Brice & Bradley wells on the south and the Choate wells on the north, there is an inclination of the limestone amounting to perhaps 10 feet in 100.

As at Spindletop, the porous limestone is not found outside the limits of the productive field. If the formation extends beyond these limits its distinctive character is lost. There is no evidence whatever of a steep marginal dip, carrying the limestone to greater depths than the outlying wells have reached.

A HIGHER POROUS LIMESTONE.

In the southeast corner of the Paraffine 30 acres there is said to be a minor limestone of the typical porous character at a depth of about 600 feet and having a thickness of 5 or 6 feet. In the latter part of 1904 a few wells were drilled into and finished in this limestone, deriving their oil from it as others did from the deeper porous formation. These wells yielded at the start about 150 barrels per day each. No strainers were used. It may safely be assumed that this rock is of the same kind and had the same origin as the deeper porous limestone (see p. 45).

SUMMARY.

The form of the limestone may be summarized as follows: (1) The general dip is very small. (2) There are at least two, and perhaps three or four, roughly dome-like or ridge-like elevations. (3) The extreme difference in elevation between the highest and the lowest points of the same formation is less than 125 feet. (4) The attitude of the limestone probably agrees with the bedding in the main but not in detail. (5) The peculiar limestone in which the oil is found probably does not exist beyond the limits of the oil field. (6) Limestones of the same character and the same (secondary) origin may occur at higher levels.

OCCURRENCE OF THE OIL.

IN THE LIMESTONE.

So far as known the porous limestone, wherever encountered, was filled with oil, and no oil has been found below it. Until the advent of salt water most of the wells were drilled into and finished in this limestone. When these deeper wells began to go to water it became the custom to finish wells at higher levels, where the occasional sands (and apparently in some cases the clays) were found to be saturated with oil.

IN THE SANDS.

As stated above, sands form a very small proportion of the sedimentary beds below 200 feet. There is no stretch of 100 feet, however, in which sands have not been found in some part of the field, and there is no stretch of 100 feet between the depths of 200 and 1,300 feet at which wells have not been finished. The occurrences of oil in the sand might be grouped into certain broad and indefinite horizons, but it is probably very rare that half a dozen wells have derived oil from the same bed. What has been said of the patchy distribution and lateral discontinuity of these sandy beds at Spindletop and Sour Lake applies with equal fitness to Batson. Probably the smallest number of wells stopped between 920 and 1,100 feet. A large number found oil between 800 and 900 feet. Throughout the Higgins tract an oil-bearing horizon is said to exist between 400 and 600 feet. Even at 265 feet one well (Alert No. 3) had a typical blow-out and developed into a small gusher yielding 125 barrels of oil per day during the short time that it lasted.

SALT WATER AND GAS.

HORIZON OF SALT WATER.

All the waters encountered below 200 feet are noticeably saline, and even above that depth it has been difficult to obtain water suitable to use in boilers. At greater depths the water becomes progressively more briny. The large number of wells which stopped between 800 and 900 feet found abundant salt water below their deepest oil stratum. Indeed, the interstratification of oil and salt water is one of the noticeable characteristics of the field. This, of course, is made possible by the highly impervious clays which form the bulk of the sedimentary formations.

ADVANCE OF SALT WATER.

The lowest oil-bearing horizons went to salt water first. Wells drilled as early as January noted its presence, though not finding it in inconvenient quantities. The first two weeks of March marked the rapid invasion of the limestone by the salt water, and it was not long before the drilling of wells to this horizon had ceased entirely.

In a general way the advance of salt water within the limestone has been from the deeper to the shallower wells, though such a rule would not apply in detail. An illustration taken from the east side of the field is typical of the behavior of the salt water in the better-known fields of the eastern United States. The Higgins No. 1 (limestone 1,198 feet deep) began to produce salt water February 25, and by March 8 the water had advanced 500 feet to the west and had invaded the Hughes well (limestone 1,170 feet deep) and the Prather No. 1 (limestone 1,162 feet deep). The advance continued westward to slightly shallower wells, reaching the wells of the Batson Oil Company in the middle of the Brice & Bradley tract on March 11 and the Moonshine Company's lease about a week later.

RELATIONS OF GAS, OIL, AND WATER.

The mutual relations of gas, oil, and water, which are regarded as typical in the Appalachian fields (see p. 116), are better exemplified at Batson than in any other field in the Coastal Plain, though even here good examples of such relations are exceptional. Not less than half a dozen wells have come in as "gasers," have later become good oil producers, and later still have gone to salt water. The parallel with the Appalachian fields is the more strict because of the fact that the wells originally producing gas are found at higher points of the faintly dome-like structure. The Wing No. 4 and Marshall Nos. 1 and 2 are good examples.

HOT WATER.

A considerable proportion of the salt water from the deeper wells was found to have a temperature above the normal for the depth from which it came. In the Higgins No. 4 the salt water from the sands 1,080 to 1,130 feet deep had a temperature of 101° F. In the Higgins No. 1 the temperature of the very briny water from a depth below 1,200 feet is said to have been 125° F. It is generally said by gagers at Batson that the temperature of the salt water is higher than that of the oil, and that there is, accordingly, a notable increase in the temperature when a mixture of oil and salt water begins to take the place of the pure oil. (Compare Jennings, p. 100.)

PRODUCTION.

NUMBER OF WELLS.

Up to August 15, 1904, 440 wells had been drilled. There were 42 new wells drilling at that time and 25 derricks were erected at which drilling had not yet begun. Fifty-eight of the completed wells were reported as dry or abandoned. Of the remaining 382, some of which produced only intermittently, it was estimated that an average of 160 were in daily operation.

QUANTITY OF OIL.

In the year 1903 the recorded production of the field was but 4,500 barrels. Its growth and decline in 1904 are best illustrated by the following columns of reliable estimates, given by Mr. Holland S. Reavis in the Oil Investors' Journal, January 1, 1905:

Production of the Batson field in 1904.

	Barrels.		Barrels.
January	440, 000	August	585, 900
February	1, 849, 000	September	435, 000
March	2, 608, 200	October	325, 500
April	1, 050, 000	November	309, 000
May	883, 500	December	316, 200
June	720, 000		
July	682, 000		10, 204, 300

It will be seen from this decrease that the production per day at the close of 1904 was approximately 10,000 barrels. At that time steel tanks were rapidly being removed to newer fields and the amount of new drilling in progress did not indicate much hope on the part of the operators that the production of the field would be revived. In the early part of 1905 the daily production rose again, reaching at various times about 15,000 barrels. In October of the same year the field continued to produce more than 9,000 barrels daily and considerable drilling was still in progress.

CHARACTER OF THE OIL.

The lightest oil yet found in any quantity on the Coastal Plain is obtained at Batson. That from the Brooks well No. 1 (J. M. Guffey Petroleum Co.) at 1,150 feet had a gravity of 29.9° B. The oil from the sands above is a little heavier, that which was taken from near the center of the field at a depth of 1,100 feet having a gravity of 26° B. The oil obtained at 265 feet in the southern end of the Paraffin 30 acres had a gravity of 20° B. In this vicinity some oil taken from so shallow a depth as 814 feet had a gravity of 29.8° B., which is about that of the deepest oil in the field. This circumstance suggests a rapid or easy rise from the lower horizon, a suggestion which is supported by the finding of a porous limestone (supposedly concretionary) at 600 feet. This is also in harmony with certain reports from drillers to the effect that in certain deep wells in that vicinity the limestone was found "fractured." The evidence on which such a report was made was not obtained.

The average gravity of Batson crude, as it is received by the United Oil and Refining Company, of Beaumont, is 27.7° B. By others the average gravity is given as low as 23° or 24°. On refining, it yields 6.5 per cent gasoline, 20.4 per cent kerosene, 14.4 per cent solar, 46.7 per cent lubricating oil, and 6 per cent asphaltum.

SARATOGA FIELD.

HISTORY AND SURFACE INDICATIONS.

SIMILARITY TO OTHER FIELDS.

The surface indications of oil at Saratoga were very similar to those at Sour Lake and Nacogdoches. The escape of small quantities of gas had long been noted, as had likewise small seepages of oil. There are also here, as at Sour Lake, certain spots in which the soil is found to be impregnated with an asphaltic substance. These phenomena have from the earliest settlement been regarded as indications of the presence of oil. A further analogy with the Sour Lake field is found in the sulphureted and sour waters which come to the surface in small quantities. In that part of the field which is thus characterized a pond was dug some years ago which resembles the partly artificial pool at Sour Lake.

The first attempt to find oil by drilling was made with a spring-pole device worked by hand. This was not far from the present site of the hotel. The drilling stopped at a small depth after obtaining a showing of heavy oil, which was bailed out in very small quantities. This oil was used for medicinal purposes only. In 1896 Savage Brothers drilled a hole in the same locality to a depth of 250 feet. Oil and water issued from this well with a natural flow, which continued at a very slow rate almost to the present time.

RECENT DEVELOPMENT.

After the opening up of the Beaumont field in 1901 drilling was begun in earnest at Saratoga. The year 1903 was the first in which oil was shipped. In that year the field is credited with a production of 150,000 barrels. Up to August, 1904, some $200,000 had been spent in development work, chiefly by a few large companies, the Southern Pacific and Santa Fe railroads, the J. M. Guffey Petroleum Company, and the Producers Oil Company being the principal operators in the field. The daily production had never exceeded 1,500 barrels for any considerable length of time. At that time a well drilled by the Guffey Company to a depth of some 1,500 feet in the southwestern part of the field gave new encouragement for drilling, and activity in the field was greatly stimulated. It was not until the following January, however, that the results of this deep drilling began to have a great effect upon the output of the field.

LOCATION AND TOPOGRAPHY.

The Saratoga field lies some 12 miles north by west from Sour Lake and is reached by a 10-mile branch of the Santa Fe Railroad which leaves the main line at Bragg. The field is on the outcrop of the Columbia sands as mapped by Kennedy. The soil is very sandy and the surface forested. Lying, as it does, close to one of the larger branches of Pine Island Bayou the sandy surface is considerably dissected, the total relief within a radius of a mile being perhaps 15 or 20 feet. There is at present no indication of any elevation of the surface due to such constructional agencies as made the Spindle Top mound.

GEOLOGIC FORMATIONS.

SOURCE OF INFORMATION.

Knowledge of the geology of the field is based almost entirely on well data. The most valuable information was obtained from sections of the following wells:

Partial list of wells in the Saratoga field.

[The numbers on the left correspond to those on the map (fig. 2).]

1. Greer.
2. Light and Power.
3. Producers No. 1.
4. Producers No. 2.
5. Producers No. 3.
6. Producers No. 4.
7. Rio Bravo No. 200.
8. Rio Bravo No. 201.
9. Rio Bravo No. 202.
10. Rio Bravo No. 203.
11. Rio Bravo No. 204.
12. Rio Bravo No. 212.
13. Santa Fe No. 1.
14. Santa Fe No. 2.
15. Santa Fe No. 3.
16. Santa Fe No. 4.
17. Santa Fe No. 5.
18. Santa Fe No. 6.

SAND AND GRAVEL.

All the formations encountered in drilling are sediments of the ordinary Gulf Coastal Plain type, generally unconsolidated. A list of the varieties of sediment found in any one oil field of the Texas Coastal Plain would be very much the same as the corresponding list taken from any other of these fields. The several varieties, however, would differ in their relative abundance in the different fields. In most cases clay would be found to lead in amount. In the Saratoga field, however, the proportion of sandy sediment is almost as great as that of clay. In the Santa Fe well No. 3 out of the first 658 feet of sediment 500 were found to be sand or gravel. This is an exceptionally high proportion, but a proportion of sand approximating one-half in the first 500 or 600 feet is not uncommon. In exceptional cases the sands have become sandstones, but such occurrences do not represent any widespread consolidation. The instances of cemented sands are generally near the surface and should probably be regarded as concretionary. Gravel has more frequent mention in the Saratoga field than elsewhere, except at Jennings, La. It appears also to be in thicker beds and of greater lateral extent than in any other Texas field.

LIMESTONE.

Thin plates of limestone are found here as in the other fields described. There is also some mention of "soapstone," which term may be used by the drillers to designate a clay, but as it appears from the reports to be in relatively thin beds it is highly probable that the term as here used has been applied to the sticky marls which, under other conditions, have been consolidated into thin beds of limestone. The frequent mention in some well records of "hard white gypsum" is believed also to refer to the same class of beds. All the sediments show the same lack of lateral continuity which has been noted in the other fields.

ZONES.

While any one bed, whatever be its composition, may pass laterally into a bed of any other composition, and the drill is therefore liable to encounter almost any material at almost any depth, there are certain horizons which are characterized by a large predominance of one kind of material. As an illustration of this, there is in almost all of the wells in the southwestern part of the field sand or gravel, or both, at a depth approximating 500 feet. That this occurrence represents merely a horizon abounding in local sands and gravels and not one continuous stratum is plain from the diversity in thickness, number of beds, and depth reported (see fig. 3). Thicknesses vary from a few feet to more than a hundred. In one well there may be but a single bed of great thickness; in another near by the sands or gravels at approximately the same horizon may appear in half a dozen beds separated

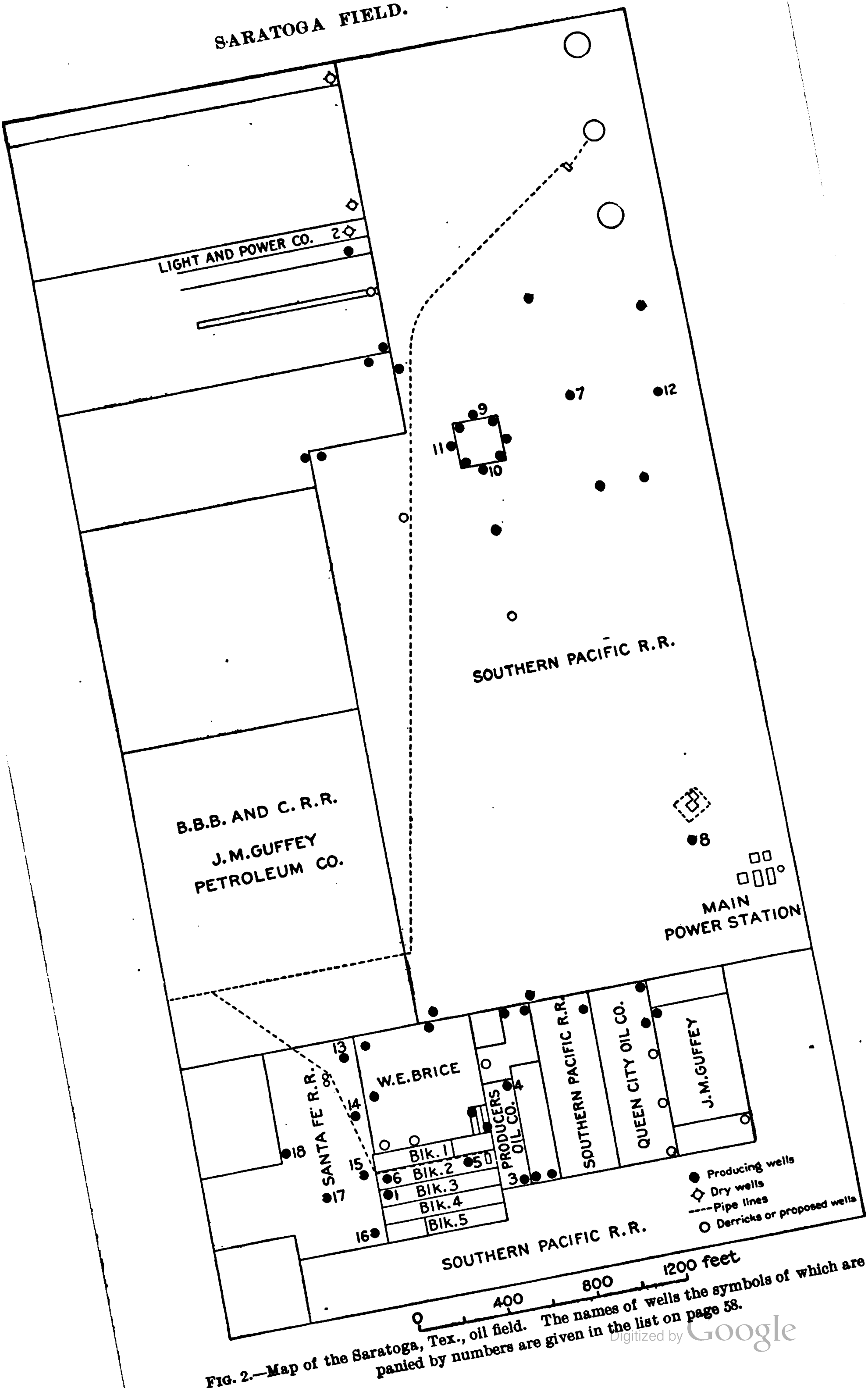

FIG. 2.—Map of the Saratoga, Tex., oil field. The names of wells the symbols of which are accor

panied by numbers are given in the list on page 58.

by intervening clays. The minor diversities of depth would require that any scheme of correlation should hypothesize sharp folding of these unconsolidated sediments. In the same part of the field (the southwest) depths between 800 and 900 feet generally show sands to which the description given above would apply. In at least a small part of this quarter of the field a thick sand has been found in all the deep wells between 1,400 and 1,500 feet. It is possible that this sand is a single and well-defined bed. In the northern part of the field sands have been found quite generally at depths between 900 and 1,000 feet. Above this sandy horizon, for a thickness of from 200 to 400 feet, little sand is found, the sediment being almost entirely clay. The same is true of the 100 or 200 feet of sediments overlying the sandy zone found at a depth of 800 feet in the southwestern part of the field.

While the sandy zones here described are not to be understood as continuous strata, but rather as large thicknesses within which limited beds of sand are very frequent, it may still be true that these small beds are so thickly crowded as to afford continuous passage for fluids (see fig. 12, p. 119). For example, it seems certain that in the southwestern part of the field the 500-foot horizon of sands and gravels is for all practical purposes an artesian stratum. It is, however, distinguished from an artesian stratum, strictly so called, by the fact that its varying depths at different places do not indicate dips of the beds. This being the case, it is impossible to infer from even a large list of depths, however carefully correlated, what the depth of the sand might be at any other place, however near.

OCCURRENCE OF THE OIL.

DEPTHS.

Showings of oil are found at almost any depth and at irregular intervals. There is no considerable thickness of sediment which does not in some part of the field afford a showing of oil or gas. In the southwest quarter of the field oil in commercial quantities has generally been found in the sands at a depth of 800 or 900 feet. The deeper oil, which has been obtained from a small spot in this part of the field, is found in the thick bed of fine sand encountered at a somewhat uniform depth of about 1,400 feet. In the northern part of the field most of the oil has been found between 900 and 1,000 feet deep. In each case the almost complete absence of sands from the next higher clays has given to the latter the character and function of a cap rock.

GAS AND BLOW-OUTS.

The oil in this field is not generally accompanied by the large amount of gas found in the rock wells of Spindletop, Sour Lake, and Batson. With the exception of a few wells, gushing has been of a milder type than that of the other fields named. However, while gas does not usually accompany the oil in large quantities, it is abundantly present in separate bodies. No field in Texas (Humble excepted) has furnished such spectacular blow-outs as Saratoga. Generally the beds from which these violent eruptions have occurred are in the upper half of the well section; that is, above the clay zone which overlies the oil. In the northern part of the field large quantities of gas were found at about 500 feet. In the Rio Bravo No. 215 there were blow-outs from depths of 200 and 600 feet. The same company's well No. 211 probably furnished the most violent example. A pocket of gas was struck at approximately 500 feet, giving rise to a blow-out so violent that the surrounding ground was affected by cracks to a distance of 250 feet. From these cracks there were eruptions of mud at distances of at least 200 feet from the mouth of the well. A crater was formed a few rods in diameter and more than 20 feet deep. The machinery and the wreck of the derrick were swallowed. To save the boiler, which stood some 200 feet away, the workmen took the precaution to anchor it to a tree. The danger of such occurrences was for a time one of the chief difficulties in drilling in this field. At least one similar blow-out, though less violent, occurred from the 1,400-foot sand, or at about that depth.

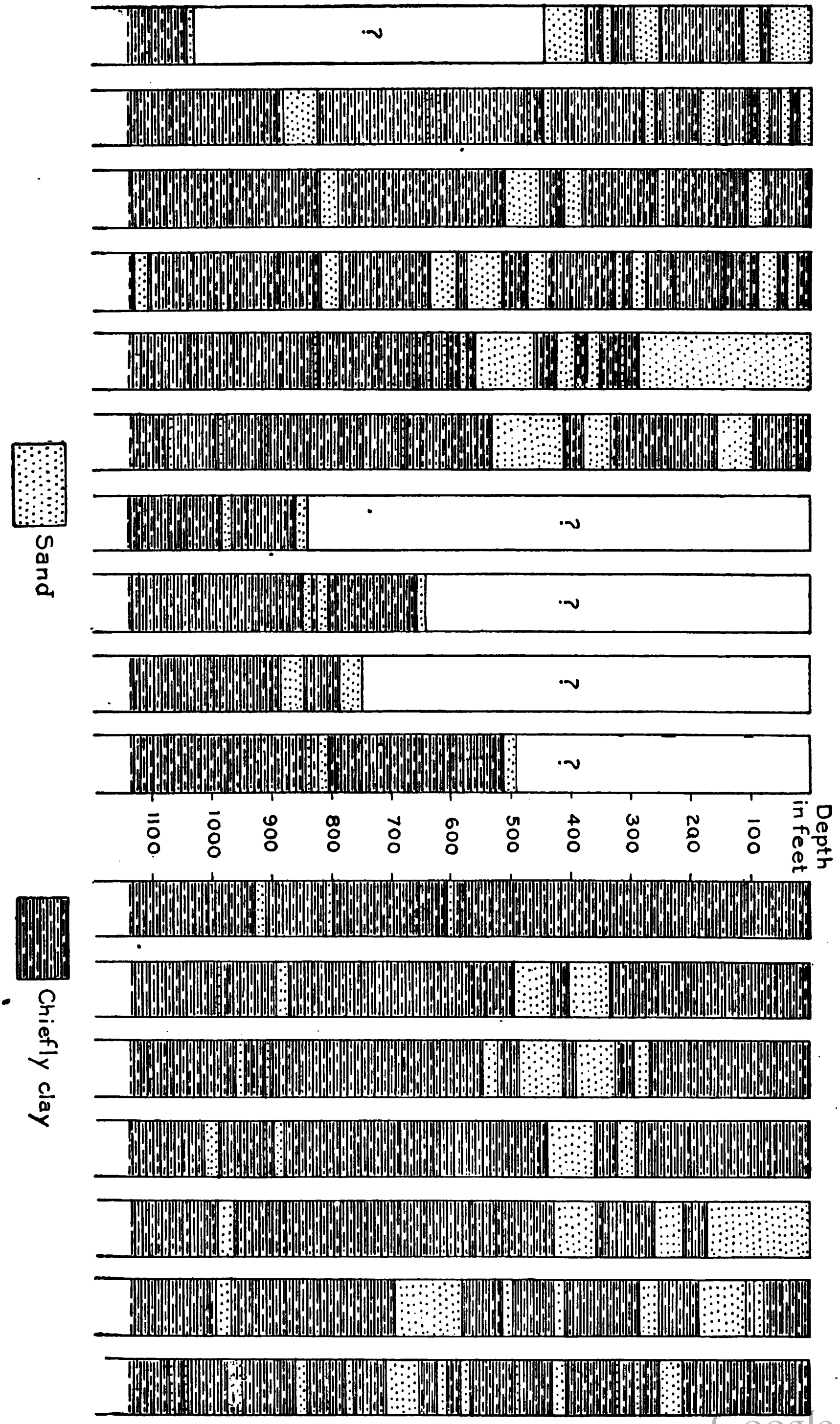

FIG. 3.—Sands in Saratoga wells, showing irregular distribution. The average distance from well to well in each group is between 300 and 400 feet. The logs of five wells in group 1 are incomplete.

WATER.

The ground waters of this field are fresh to a much greater depth than those of the other Hardin County fields. The strong flow usually met at a depth of about 500 feet in the southwestern part of the field is always reported as fresh. It appears that, by ill fortune or carelessness, this water was not properly cased off in certain wells. When the wells were drilled through the underlying clay, this water was given access to the sandy zone containing the oil and soon appeared in other wells, which had been pumping oil alone. The admixture of this water was the more unfortunate on account of the fact that fresh water is separated from the oil with greater difficulty than salt water.

Below the level of the clay zone which overlies the first important oil the water encountered is salt. The amount of salt water pumped previous to the drilling of the deep wells was small. The 1,400-foot sand, after yielding oil abundantly for a few weeks, began to produce large quantities of salt water.

One thousand feet north of the limited area in which the above-named wells are situated a number of deep wells were drilled in the B. B. B. and C. tract. This locality, while producing moderate quantities of oil, yielded salt water in great abundance, some wells producing as much as 5,000 barrels daily. One well having a depth of 1,700 feet is said to have produced hot sulphur water.

DEVELOPMENT AND PRODUCTION.

DIMENSIONS OF THE FIELD.

The developed area of the Saratoga field has a total length of about 4,500 feet north and south and a width of 1,800 feet east and west. The longest dimension has a trend a little east of north. The area of the proved field is less than 200 acres. There is some reason to think that the area of the field as here stated represents approximately the total size of the pool, and that therefore but little development may be expected outside of the present limits. It must be remarked, however, that the formations, the surface indications, and the occurrence of the oil in this field bear a striking resemblance to the corresponding features of those parts of Sour Lake and Spindletop which are not known to be underlain by the porous limestone. In view of the small area occupied by such limestone at Sour Lake, it is too early to abandon the hope that there may be found on the borders of the present Saratoga field a spot which will produce oil from the limestone, perhaps in as great abundance as at Sour Lake.

Up to August 15, 1904, there had been drilled in and around the Saratoga field 70 wells. Forty-five of these were drilled within the productive area of the field, and 35 have at some time been pumped more or less regularly. The number of wells drilled since the summer of 1904 is large.

AMOUNT PRODUCED.

As indicated above, the production of the Saratoga field up to the close of 1904 was relatively small. For the year 1903 it was 150,000 barrels. A very reliable estimate makes the output of 1904 a little more than 700,000 barrels. The production during the latter year was quite uniform, amounting in December to 65,000 barrels, or a little more than 2,000 barrels daily. Early in January, 1905, the 1,400-foot sand in the southwestern quarter of the field began to yield large quantities of oil. For a short time daily records approximating 20,000 barrels were common, but in February the advent of salt water had reduced the daily production to less than 10,000 barrels. The principal wells concerned in the temporary large output were two Greer wells (of the J. M. Guffey Petroleum Company) and the Producers No. 4. The last-named is said to have made a record of 10,000 barrels daily.

CHARACTER OF THE OIL.

The gravity of the Saratoga oil is a little greater than the average of that from adjacent fields. The larger part of that produced in 1903 and 1904 from depths not greater than

1,100 feet showed a gravity of from 16° to 18° B. The deeper oil produced early in 1905 is considerably lighter, and it has been said that tests showed a gravity of 22° B. It is not certain that these readings were corrected for temperature. The oil is of a good fuel quality, and most of it is consumed for that purpose.

MATAGORDA FIELD.

LOCATION.

The site of this field is Big Hill, Matagorda County, a few miles from the mouth of Colorado River and about 5 miles northeast of the village of Matagorda. It lies 1 mile inland from the shore of Matagorda Bay. Big Hill is a mound of the Spindletop type, rising 36 feet above the sea level and standing on a plain of 12 to 15 feet elevation. It is a fairly well-defined topographic feature and approximately symmetrical in form. It is nearly flat topped, embracing perhaps 100 acres at its highest level, though the area of the entire elevation is several times that size.

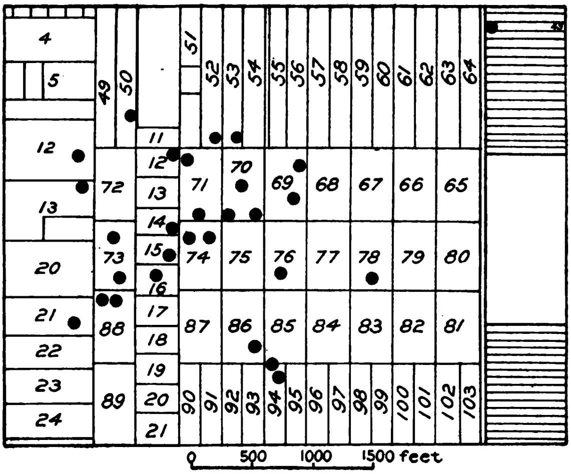

FIG. 4.—Map of the Matagorda, Tex., oil field. See list of wells, page 67.

Considerable development work was carried on in 1903 and 1904, at least 15 wells being drilled before the autumn of the latter year. The drilling of these 15 wells was not sufficient to indicate the exact boundaries of the productive territory, but all the wells which have produced oil or a large amount of gas are on or near the highest part of the mound. The Harper well, 1,370 feet deep, one-fourth mile northeast of the mound, did not strike oil, and the Santa Fe No. 1, 1,198 feet deep, one-half mile southwest of the field, gave only showings of oil, although it showed the presence of considerable gas. The Lane No. 1, on the east side, is also practically a dry hole 1,360 feet deep. Since the field was visited the total number of wells has doubled and all of the productive territory may be said to be occupied.

GEOLOGIC FORMATIONS.

WELL SECTIONS.

The following well sections are typical of this field:

Logs of wells in Matagorda field.

LANE WELL NO. 2.

[Received from W. G. Lane, driller.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Red clay	10	10
2	Red sand	70	80
3	Red clay	15	95
4	Fine gray sand	80	175
5	Gumbo	50	225
6	Sand	40	265
7	Blue gumbo or shale	220	485
8	Blue limestone (specimen seen)	4	489
9	Gumbo	141	630
10	Blue limestone	12	642
11	Sudden drop	6	648
12	Rock and sand alternating, rocks 2 to 8 feet each; a sudden drop of the drill below each rock	57	705
13	Green gumbo with shells	75	780
14	Shells	4	784
15	Gray sandstone	2	786
16	Gumbo	69	855
17	Cap rock, not passed through	4	859

Casing set 1 foot in cap rock at 856. This well showed considerable gas but little oil.

GRIFFITH NO. 1.

[Received from Dr P. S. Griffith.]

	Formation.	Thickness.	Total depth.
1	Yellow clay	20	20
2	Red sand	30	50
3	Red clay	25	75
4	Gray sand	90	165
5	Blue clay	283	448
6	Blue rock	4	452
7	Blue clay	211	663
8	Sand	20	683
9	Gumbo and shells	50	733
10	Hard rock	3	736
11	Gumbo	10	746
12	Blue rock	2	748
13	Sand	1	749
14	Blue rock and shells	16	765
15	Gumbo	4	769
16	Blue rock and iron (pyrite)	6	775
17	Blue clay and shells	40	815
18	Blue rock and shells	6	821
19	Blue rock	18	839
20	Blue clay with show of gas	11	850
21	Hard rock	2	852
22	Rock showing gas; casing set at 874	23	875

SEDIMENTS ABOVE THE OIL.

The formations passed through are very similar to those found in the oil fields of eastern Texas. Clay is the leading material in amount. There are also sands, shells, and thin beds of "rock," which is known in some cases to be limestone, while in others it may be sandstone with calcareous cement. Most of the rock beds carry pyrite, but this is far more abundant near the horizon of the oil, frequently just above it.

POROUS LIMESTONE.

At depths varying from 844 to 1,035 feet a limestone is found which possesses the characteristic feature of the oil-bearing limestone at Spindletop and other large oil fields of the Coastal Plain. Some specimens obtained are entirely crystalline and highly porous or cavernous, suggesting the probability that the rock body contains openings of still larger size. Certain fragments of this white or bluish limestone came to the surface perfectly clean and evidently free from oil. Such fragments are plainly from that portion of the rock which contained the gas accountable for the blow-outs. The thickness of this porous limestone formation is uncertain and no doubt variable. Whether the formation is single or subdivided by beds of sand is also uncertain. The cause of this uncertainty lies in the porous nature of the rock itself. This porosity causes the loss of the water used in drilling, and therefore no samples could be obtained. Under certain favorable conditions, described elsewhere, drilling advanced for many feet without a return of the water, and therefore with no definite knowledge of the nature of the rock. From the behavior of the tools it is believed that the thickness of the limestone in the Lane No. 1 is more than 100 feet, a part of which was traversed without a return of the water.

FORMATION BELOW THE POROUS LIMESTONE.

But few wells entered the formation beneath the limestone, and the knowledge of its nature is based largely on the observations made in drilling the Lane No. 1. In this well the porous limestone or "gas rock" was found at 1,035 feet, and a large proportion of its body was found to be of sulphur, which filled the caverns. Beneath this mixture of limestone and sulphur the drill entered a nearly white sticky substance which was said to be similar to putty or sometimes to white lead. The material, when brought to the surface and dried, formed light porous chunks, which were said to resemble chalk. The description of this material, which agrees closely with that of certain materials examined in other fields, leads to the inference that the formation underlying the porous limestone is a marl, in places doubtless sandy, and perhaps passing into a pure sand at other places.

SULPHUR.

Sulphur is reported from various wells, but always at or near the horizon of the oil. As in the better-known oil fields, it exists either in a disseminated form in the sand or clay or as a pure crystalline mass, filling the caverns of the limestone. In the latter form it has already been mentioned as occurring in the Lane well No. 1. It is here reported as "60 feet of solid sulphur with a probable addition of 30 feet more." Other good observers, however, speak of this sulphur as "mixed with rock," and inasmuch as a part of the drilling was effected without a return current of water, and in view of the fact that the material when returned is in an unsatisfactory form for the determination of the relations of several materials coming up together, it is highly probable that the assumption of sulphur in caverns is correct for this place, as it is known to be for certain other places. In the same well (Lane No. 1) it is observed that there were small "veins" of sulphur in the light-colored sticky mass below the limestone. The Dean well, the Johnson, and the Griffith No. 2 each report a little sulphur at about the horizon of the oil.

STRUCTURE OF THE MOUND.

There is no other mound in which the depths of the porous limestone in different places may be so conveniently correlated to show dips as at Matagorda. Of the wells drilled previous to September, 1904, the Dean reached the limestone at the least depth (844 feet). This well is on the west side of the field. East of the Dean well the Griffith No. 2 found the same limestone at 850 feet, and the Griffith No. 1, still farther east, at 852 feet. The Lane No. 2, which is north of the Dean, went 856 feet to the porous limestone. Northeast of the Lane the Higgins and Johnson wells went 865 feet and 870 feet, respectively, to the same rock. The Harper well, one-fourth mile to the northeast, found nothing but sand and clay to a depth of 1,370 feet. South from the Dean and Griffith wells the Santa Fe No. 2 found rock at 855 feet, and the wells at the south end of the field at 872 feet. On the east side of the field the Lane No. 1 struck what is presumably the same rock at 1,035 feet. The Santa Fe No. 1, southwest of the field, though nearly 1,200 feet deep, found nothing which could be identified with the limestone in question.

The depths given above indicate that that part of the porous limestone which is known has the form of a half dome, its highest part being at the middle of the west side of the field. Its dip toward the northeast is at least 26 feet in the 500 feet between the Lane well and the Johnson well. The corresponding dip to the southeast is 28 feet to the southern border of the field, 2,000 feet away. If, as seems probable, the 1,035-foot level in the Lane well is to be correlated with the other depths named, the dip at the eastern edge of the mound is greatly steepened. In accordance with the interpretation of the observations on the oil-bearing rock at Spindletop (see p. 36), it is highly probable that in this field also the limestone occupies an area but little greater than that of the surficial mound. The extreme height of the dome, so far as revealed by borings, is less than 200 feet, and it is not probable that more complete data would greatly increase this height.

OCCURRENCE OF OIL, GAS, AND SALT WATER.

The porous limestone constitutes the reservoir for oil, gas, and salt water. Gas and oil have not been found in any considerable quantity at any other horizon.[a] The distribution of the three fluids is not such as to lead to the conclusion that the limestone is porous throughout, and therefore forms but a single reservoir. If this were the case, the gas should be expected to accumulate at the top of the dome, the oil beneath the gas, and the salt water at the base of the dome, the materials thus being arranged according to their several specific gravities, as in the Appalachian fields. On the contrary, the strongest pressure and the longest continued flow of gas is found in the southernmost well of the field, in which the limestone is deeper than in any other, with one exception. The flow from this well was estimated at 5,000,000 cubic feet daily. The gas is said to be chiefly H_2S mixed with SO_2. After producing under control for more than a year the well was connected by a pipe line over 7 miles long with an irrigation pumping plant on Colorado River. A well 30 feet to the north found a similar body of gas and no oil. It was evident that these two wells tapped the same reservoir from the fact that the flow of gas from the first was interrupted until the closing of the second. A third well, probably 200 feet farther north, found sulphur salt water at a temperature of 99.6° F. A strong flow of this hot water was maintained for months. It came from a level fully 150 feet higher than that of the gas in the other two wells. It may therefore be assumed that the porous rock from which the water was derived is separated by impervious material from that yielding the gas (see p. 122).

The Griffith No. 1 found oil and gas near the base of the limestone body. From this horizon a violent blow-out occurred, projecting the pipe from the well in such a manner as to allow 300 feet to rise vertically into the air and fall as one piece. This blow-out was accompanied or followed by oil. The well began to gush some 400 barrels per day, gradually diminishing to perhaps half that amount, but producing some 10,000 barrels before the flow ceased. The circumstances attending this cessation of flow furnish an additional illustration of the communication and interdependence of certain wells in the Matagorda field. During the continuance of the flow from the Griffith No. 1, No. 2 was drilled several hundred feet farther west. This well encountered gas at about the same horizon, but with very little oil. In order to drill the well deeper it became necessary to stop the flow of gas by pumping in slush or mud to fill the pores of the rock. After this process had been continued for a long time and under great pressure (approximately 400 pounds) well No. 1 ceased to flow. It is believed that the mud pumped into well No. 2 entered and clogged the pores of the same rock from which the gas and oil of well No. 1 were obtained.

In several instances the gas from one well has been successfully used to "blow" another, after the manner of blowing with compressed air (p. 123). The gas of the Dean well was thus introduced into the Johnson well and for a time expelled about 3,000 barrels of fluid daily, fully 90 per cent of which was salt water. The gas of the Griffith No. 2 was similarly used in the Griffith No. 1, blowing out in one night 1,000 barrels of oil in addition to salt water. With the continuance of the process the water increased in proportion until, out of 10,000 barrels of fluid per day, only an insignificant amount was oil.

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[a] Data on this point were not obtained for the wells drilled since 1904.

PRODUCTION.

The Matagorda field continued to grow in importance until December, 1904. In the early part of that month, out of about 30 wells drilled, 14 were producing. The combined daily output was more than 4,000 barrels. Salt water appeared in every well, probably from the first, but late in December it came in such quantities that the production of the field fell quickly to 1,200 barrels a day, and by February 1, 1905, the daily amount was not above 400 barrels. At that time 32 wells had been drilled and 2 others were nearly complete. Of these, 11 wells were producing, a number of others having been abandoned after pumping for a time.

The following is a list of wells drilled up to May, 1905. The locations of most of these are shown on the map (fig. 4, p. 63).

Wells on Big Hill, Matagorda County.

Owners.	No. of block.	Number of wells.	Owners.	No. of block.	Number of wells.
P. S. Griffith	70	3	P. S. Griffith	16	1
—— Johnson	53	1	J. C. Walker	73	2
Griffith & Sutherland	69	1	Santa Fe R. R. Co	88	2
Bay City Oil Co	69	1	P. S. Griffith	21	1
Big Hill Oil and Fuel Co. (Dean)	12	1	do	94	2
Big Hill Oil and Fuel Co	74	5	Myers & Lovejoy	13	1
Do	75	1	Higgins and Heywood companies	52	1
Santa Fe R. R. Co	76	1	—— Lane	71	3
Lane & Sutherland	78	1	Bay City Oil Co	71	1
P. S. Griffith	14	3	Johnson & Underwood	71	1
McKallip Bros. & Miller	15	1			

HUMBLE FIELD.

HISTORICAL ACCOUNT.

The field at Humble was opened up after the completion of the field work which forms the basis of this report. Most of the data from which this brief account is compiled were published in the Oil Investors' Journal between November, 1904, and May, 1905.

The Humble field is in Harris County, 18 miles north of Houston and 1½ miles east of Humble station, on the Houston, East and West Texas Railway. It covers a part of Echols Ridge, and is 100 feet above sea level, or 50 feet higher than Houston.

The escape of gas in this vicinity has been noticed for many years. In the autumn of 1902 Mr. George Hart attempted to drill a well west of the present developed field, but the drilling was stopped by a blow-out. In the summer of 1904 Mr. C. E. Barrett, of Houston, drilled several wells in that part of the field known as "the hill." Most of the wells in this part of the field were ruined by blow-outs. In October the Higgins Oil and Fuel Company brought in a large gas well about one-half mile southeast of the Barrett wells.

The first successful oil well was the Beatty No. 2, completed January 7, 1905. For some days this well yielded 8,500 barrels per day. Other producers followed in rapid succession. Some of these yielded more than 10,000 barrels daily. Before March 1 the daily production of the field was nearly 90,000 barrels and within three months after the completion of the Beatty No. 2 the field had produced 3,000,000 barrels of oil. Previous to March 3 little salt water was observed. On that day, the first anniversary of the "inundation" by salt water at Batson, the water began to appear in the great gushers at Humble. In ten days the production fell from nearly 90,000 barrels to less than 25,000 barrels daily. Partly by the bringing in of new wells on the east side and partly by the renewal of flow from the wells which had been "drowned out" the field recovered its former production, so that the yield in April was nearly 2,000,000 barrels. The Beatty well No. 2, which stopped flowing on the advent of the salt water, began again to flow, and produced 4,800 barrels of oil in one day. The production of the field soon began to decrease again, and in November, 1905, it was but little more than 20,000 barrels per day.

GEOLOGIC FORMATIONS.

As seen from the following log, the formations passed through in drilling are similar to those of the other fields. In other wells a large number of thin beds of rock are reported.

Log of Westheimer well, in Humble field.

[Received from Sid. Westheimer.]

	Formation.	Thickness.		Total depth.	
		Ft.	*in.*	*Ft.*	*in.*
1	Surface soil	4	0	4	0
2	Joint clay	80	0	84	0
3	Water sand	20	0	104	0
4	Clay	23	3	127	3
5	Red and blue clay mixed	165	2	292	5
6	Same as above, with some gravel	127	8	420	1
7	Yellow and blue clay	43	7	463	8
8	Very sticky clay	43	9	507	5
9	Not reported	30	7	538	0
10	Hard rock	1	0	539	0
11	Blue gumbo	5	4	544	4
12	Water sand and gravel	1	0	545	4
13	Hard blue clay with some gravel	2	11	548	3
14	Blue clay and blue gumbo	39	4	587	7
15	Quicksand with black specks and heavy gas pressure	21	5	609	0
16	Not reported	21	10	630	10
17	Blue and brown clay mixed, very tough	209	8	840	6
18	Gypsum (?)	4	4	844	10
19	Rock with iron pyrites and sulphur	38	3	883	1
20	Blue clay mixed with some yellow clay	43	6	926	7
21	Rock	1	0	927	7
22	Not reported	17	5	945	0
23	Sand showing carbon (?), iron, gas, and soft yellow sulphur	6	0	951	0
24	Mixed clay	17	7	968	7
25	Mixed clay and thin layers of rock	39	4	1,007	11
26	White sand	2	0	1,009	11
27	Brown, yellow, and red clay, some soft rock	43	8	1,053	7
28	Same clay with 5 feet of soft white shale and gas	42	4	1,095	11
29	Yellow and blue clay with sulphur; strong gas pressure	40	0	1,135	11
30	Not reported	43	11	1,179	10
31	Yellow clay mixed with white lime gravel	42	0	1,221	10
32	Soft sand rock; gas-bearing and very porous	42	3	1,264	1
33	Yellow, red, and blue clay mixed with white soft gravel	152	1	1,416	2
34	Small white gravel and gas	41	3	1,457	5
35		42	11	1,500	4

This well is one-half mile east from Humble station.

Some of the Humble wells are said to derive their oil from "rock." The Beatty No. 2 was drilled through 80 feet of hard rock, beneath which it found oil in softer material. As no strainer was used, it is probable that the oil of this well and some others comes from a porous limestone. The depth of the overlying rock is a little more than 1,200 feet.

GAS.

This field is remarkable for its large supplies of gas and terrific blow-outs. Gas was first found in large quantities between 500 and 600 feet deep. The strongest pressures were encountered at about 800 feet. From this depth there occurred, December 13, 1904, in the Higgins No. 2, the most violent eruption recorded in the Texas fields. After emitting gas, water, sand, and chunks of clay for some hours, the casing became choked, but apparently the gas rose outside the casing to the higher sands between 500 and 600 feet from the surface, "and by the morning of the 14th this abnormal pressure sought relief through the various wells that had reached that depth on the neighboring properties." Every well within a considerable radius became involved in a general eruption of gas, water, and sand.

As in the other large fields, the great blow-outs were from horizons above the main oil body. The gas found at these levels is not of the poisonous type. That which has been confined with the oil and comes out with it from the great gushers is of the same deadly character as the corresponding gas at Spindletop.

Before the bringing in of the great producers at Humble a "blow-out preventer" had been devised. It was used with success at the finishing of the Beatty No. 2, the first great gusher.

The Humble oil closely resembles that of the other fields. The large production caused a great fall of prices. Up to June, 1904, little or no oil from the Humble field brought more than 16 cents per barrel, and the larger part was sold much cheaper.

MINOR TEXAS DISTRICTS.

NACOGDOCHES COUNTY.

A considerable area some 15 miles southeast of Nacogdoches has been known for nearly forty years to contain deposits of a heavy brown oil suitable for lubricating purposes. In the ten years following 1887 there was a considerable development of the industry, and probably at least 100 wells were drilled. Perhaps half of these yielded some oil, but the amounts in all cases were small, varying from a fraction of a barrel to a possible 5 or 6 barrels per day. An occasional pump was installed, but most of the oil was bailed out. The Lubricating Oil Company, having 20 wells in operation in 1890, shipped its products by wagon to Nacogdoches. The Petroleum Prospecting Company built a pipe line to Nacogdoches, where its oil was tanked. This pipe line (the first in the State of Texas) has since been taken up. The field is now idle, though it is understood that this does not indicate a failure of the wells. A keeper is employed by the present owners to reside at the holdings.[a]

The Nacogdoches field is in the East Texas Timber Belt. At this place the relief of the Coastal Plain, due to erosion by Angelina River and its tributaries, is from 100 to 200 feet. The underlying rock is Eocene, chiefly greensands, which in weathering have produced a brick-red soil. There are occasional outcrops of shales and sandstones, but the bedding is so irregular that dips and strikes taken from these limited exposures are of little value in determining structure. The occurrence of oil, therefore, is not known to have any other relation to geologic structure than that of its presence in local beds of sand overlain by clay and greensand.

Most of the superficial phenomena associated with the oil fields of Texas have been noted in the Nacogdoches field. The bubbling up of gas is common. At places each bubble rising through water leaves a film of oil on the surface. At Oil Spring, a well-known "boiling spring," brown globules of oil are seen rising through the water and forming iridescent films as they spread out upon its surface. Seepages of oil are common along the banks of streams. There are also sulphureted waters containing in small proportion certain sour salts. Iron pyrite, from the decomposition of which these salts may have been derived, is encountered in drilling. A scum of iron oxide derived from the soil is a very common occurrence in Nacogdoches County and other counties in which the red soils are found. Such scums are frequently mistaken for films of oil.

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[a] For a more detailed history of the development of this field, see Phillips, Dr. William Battle, Texas petroleum: Bull. University of Texas Mineral Survey No. 1, 1900, p. 1.

Most of the wells are in two large groups. One group follows the valley of Mast Creek, a northern tributary of Angelina River; the other is on the lowlands surrounding Oil Spring, 3 miles southwest of the first group. It was in the territory occupied by this latter group of wells that oil was first discovered, and most of the shipments have been from these wells.

The prevailing depth at which oil is found is from 70 feet to a little more than 200 feet. Far the larger part of the oil has probably come from less than 100 feet deep. The wells on Mast Creek are now filled with water up to the level of the surface of ground water. The water is covered with oil, varying in amount in different wells from a thin coating to a column 1 foot in depth. In some of the wells around Oil Spring the oil stands at a level considerably above that of the ground water. From one well there is still a slight natural flow from the mouth of the pipe 3 feet above the ground.

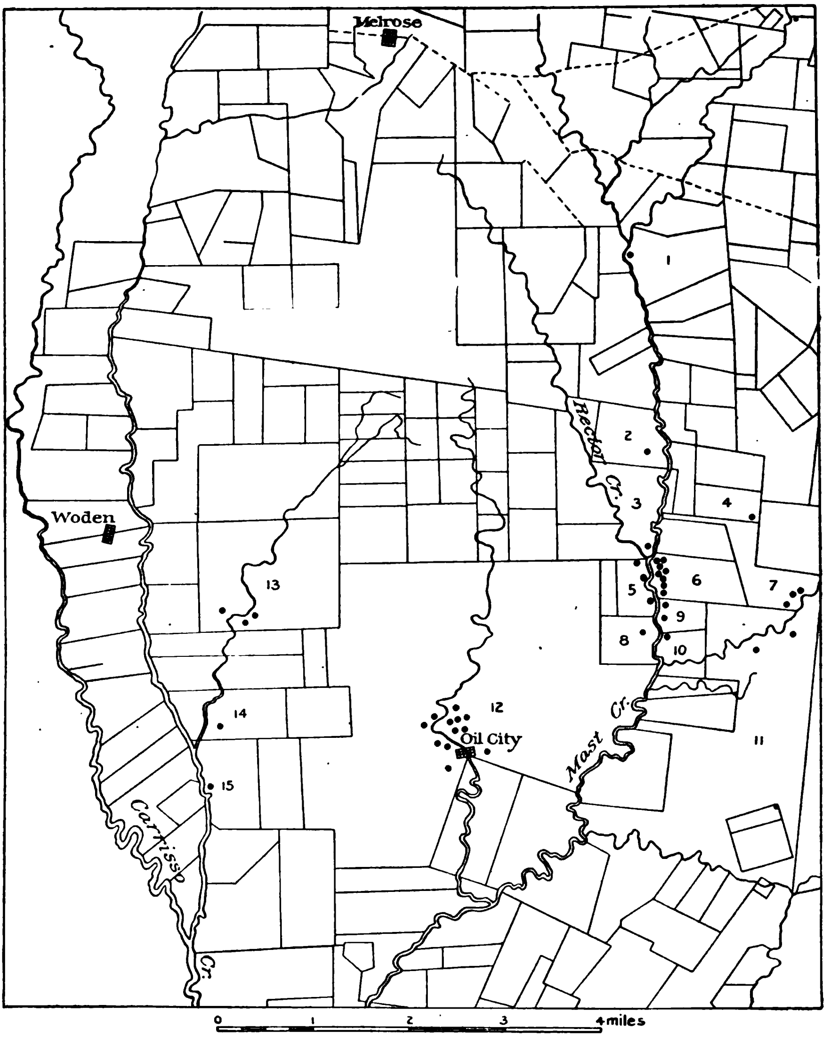

FIG. 5.—Part of Nacogdoches County, showing location of oil wells.

A well 684 feet deep on the Skillern homestead, between Mast and Rector creeks, gave the following section:

Log of Skillern homestead well, Nacogdoches County.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Clay	47	47
2	Rock, with shells	7	54
3	Blue marl	26	80
4	Sand, with slight show of oil	8	88
5	Blue clay	56	144
6	Hard rock	7	151
7	Blue clay	37	188
8	Sand, with oil signs	6	194
9	Hard, dark-blue clay	44	238
10	Sand	38	276
11	Rock, with streaks of sand from 8 to 10 feet	18	294
12	Coarse sand, good showing of oil	5	299
13	Blue clay (set 10-inch pipe in rock)	41	340
14	Hard rock	9	349
15	Stiff blue clay	38	387
16	White sand; artesian water	18	405
17	Hard blue clay and some rock	53	458
18	Thin rock, with sand	31	489
19	Porous rock; sulphur	8	497
20	Coarse sand; some gas	17	514
21	Hard rock	4	518
22	Bed of shells; some gas	7	525
23	Stiff blue clay (gumbo)	34	559
24	Porous soft rock	4	563
25	Sand, slight sign of oil	9	572
26	Black formation of asphalt, dry	9	581
27	Gumbo or blue clay	31	612
28	Hard rock	4	616
29	Shells, with gravel	8	624
30	Gumbo	27	651
31	Thin rocks, with sands between	13	664
32	Hard, flinty rock	3	667
33	Dark, coarse sand, or oil sand; good show of oil	6	673
34	Porous rock, soft	5	678
35	Sand, dark with asphalt	3	681
36	Hard rock	3	684

It will be observed that in this well much stiff clay was passed through, and there were at least seven horizons of coarse sands in which were found showings of oil or gas, or both. Attention is directed to the porous rock containing sulphur, passed between 486 and 497 feet; specimens were not seen. At greater depths are two beds called "asphalt," or "sand with asphalt." A well 2 miles south of Melrose and 6 miles north of Oil Spring was sunk 255 feet in clay, sand, and greensand, finding a showing of oil at about 160 feet beneath nearly 40 feet of clay.

Near Carrisso Creek, 3 miles west of Oil Spring, a deep well was being drilled by Mr. J. M. Thrasher at the time the field was visited, in the summer of 1904. The well had then attained a depth of 400 feet. Most of the beds passed through were greensand, of various shades and various degrees of induration. Oil was found in small quantities at 365 feet.

JASPER AND SAN AUGUSTINE COUNTIES.

At many places in the East Texas Timber Belt there are surface indications similar to those near Nacogdoches. The best known of these localities are in San Augustine and Jasper counties.

The Santa Fe Railway Company has drilled three wells near San Augustine. Most of the beds passed through were clay or sand. A few showings of heavy dark oil were noted. Well No. 1 is the deepest of the three. The following log is typical:

Log of Santa Fe No. 1 well, San Augustine, Tex.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Red clay	15	15
2	Yellow clay and marl	5	20
3	Blue marl	14	34
4	Blue marl, black as coal when wet	10	44
5	Blue marl, streaks of harder	8	52
6	Blue marl	5	57
7	Blue clay	12	69
8	Brown shale	3½	72½
9	Brown, soapy shale, with bowlder of hematite at 75 and 78	9½	82
10	Brown, soapy shale	7	89
11	Brown soapstone and thin layers of limestone	7	96
12	Blue marl	8½	114½
13	Blue clay	1	115½
14	Blue and brown shale, with hard streaks	17	132½
15	Blue limestone and marl, with pyrite; very hard	6½	139
16	Gray water sand, hard	2	141
17	Gray water sand, a little pyrite, and very small trace of oil and gas	26	167
18	Blue gray water sand	6	173
19	Brown clay, with sand	14	187
20	Brown sand, with streaks of clay	11	198
21	Brown water sand	10	208
22	White clay	1	209
23	Brown gumbo and clay	29	238
24	Pyrite	2	240
25	Water sand	10	250
26	Water clay	10	260
27	Black rock and pyrite	1	261
28	Brown clay	6	267
29	Bowlder of lime, with little oil	1	268
30	Brown clay	2	270
31	Brown clay, with layers of sand	4	274
32	Fine sand	1	275
33	Brown clay	2	277
34	Fine sand	1	278
35	Brown clay	5	283
36	Bowlder of lime	2	285
37	Brown clay	5	290
38	Brown sand	4	294
39	Brown clay, with layers of sand	10	304
40	Not reported	24	328
41	Brown clay; little oil	14	342
42	Fine sand	18	360
43	Fine sand or clay	8	368
44	Not reported	36	404
45	Clay and shells	19	423
46	Clay or fine sand	11	434
47	Shale, with layers of lignite	24	460
48	Clay or fine sand	23	483
49	Fine sand	2	485
50	Clay and little lignite	3	488
51	Clay	5	503
52	Shale	5	508
53	Shale, with little lignite	6	514
54	Shale and few shells	4	518
55	Shale	12	530
56	Lignite	½	530½
57	Shale; thin lignite layers	57½	588
58	Lignite	2	590
59	Shale	1	591
60	Lignite	4	595

The vicinity of Jasper, in Jasper County, is similar in topography and forest covering to the Nacogdoches field. The underlying sediments are of younger age, those at the surface being sands. The soil itself in many places is pure sand.

At various places in this county there are abundant seepages of oil and gas. Asphalt or "tar" is found in the soil at some places. The waters of such localities are frequently sulphureted, or contain various salts in sufficient quantity to give them a sour or bitter taste.

Twelve miles north of Jasper, in the angle between Angelina River and Ayish Bayou, is a saline a few acres in extent. The spot is bare and sandy, though surrounded by the dense jungle which characterizes the bayou bottoms. Immediately surrounding the saline is an elevated rim from 5 to 7 feet high. The origin of this elevation seems to be similar to that of the mud volcanoes within the area of the saline. The waters found here and there in small pools are slightly salt. Scattered over spots within the area, and especially over the surface of the bounding rim, are great numbers of limestone concretions, usually less than an inch in diameter. There are also some nodules of sand cemented by lime. The limestone concretions when broken generally show cracks radiating from the center, the open spaces thus formed being sometimes filled with clay.

The valley of Walnut Creek east and south of Jasper shows all of the phenomena enumerated above, except mud volcanoes. A well was drilled 1,471 feet deep on the Seale farm, 3 miles south of Jasper. At least nine different showings of oil were reported above a depth of 1,200 feet. The Ralph well, drilled by the J. M. Guffey Petroleum Company, 13 miles northwest of Jasper, is 2,277 feet deep, but with the exception of a little gas between 650 and 800 feet, nothing was reported which might suggest the presence of oil. At Bowlers Ferry, on Angelina River, not far from the Ralph well, a well was sunk to perhaps 1,200 feet, and is reported to have found some indication of oil at 995 feet. A few miles northwest of these wells, near Neches River, are the "Tar Springs." In this locality the surface seepage of heavy dark oil is sufficient to enable farmers to collect it for use on wagons and machinery.

The log of the well near Jasper was carefully kept by Prof. F. C. Thiele, of Beaumont. It affords the best information obtainable concerning the character of the sediments passed through in drilling in this vicinity.

Log of Seale farm well, 3 miles south of Jasper, Tex.

[Compiled by Prof. F. C. Thiele.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Sand	40	40
2	Water sand	20	60
3	Sand and sand rock	90	150
4	Blue clay and sand; at 275 feet, artesian water and gas; at 250 feet, oil showing	260	410
5	Lime rock	10	420
6	Blue clay	100	520
7	Lime rock	5	525
8	Gumbo and sand	150	675
9	Lime rock	6	681
10	Gumbo	23	704
11	Sand; oil showing	23	727
12	Lime rock	3	730
13	Gumbo and shale	28	758
14	Dolomitic rock, pyrites, quartz, sand; oil showing	9	767
15	Dolomitic rock, pyrites, quartz, sand, yellow clay; oil showing	19	786
16	Quicksand, dolomitic rock, gumbo	22	808
17	Gumbo, shale, gravel, dolomitic rock, quicksand, iron pyrites; oil showing	24	832
18	Dolomitic rock, quicksand, yellow clay, lignite; slight oil showing	21	853
19	Hard gray clay, calcareous concretions, lime rock, pyrites	77	930
20	Fine quicksand, concretions, much fine pyrites; splendid oil showing	11	941
21	Shale, fine quartz sand, dolomitic rock, iron oxide, calcite	79	1,020
22	Fine white sand, pyrites, shale, large amount of lime rock	40	1,060
23	Fine white sand, pyrites, shale, some lime rock	10	1,070
24	Shale, variegated pebbles, chips of flint rock, lime rock, and plenty of pyrites	2	1,072
25	Extremely fine gray sand, shell fragments, very fine white quartz, black carbonaceous matter, some clay and limestone; oil showing very good	23	1,095
26	Fine gray sand, lime concretions, some white quartz, black carbonaceous particles, considerable iron oxide	21	1,116
27	Fine gray sand, lime concretions white quartz, black carbonaceous matter, magnetic iron oxide in abundance; oil showing good	12	1,128
28	Sand rock, white quartz	42	1,170
29	Sand rock; gas and oil showing	20	1,190
30	Fine gray sand, carbonaceous particles, magnetic iron oxide	80	1,270
31	Bluish-gray clay, very fine sand, black particles, magnetic iron, quartz	50	1,320
32	Very hard blue shale	151	1,471

SABINE PASS OIL PONDS.[a]

THEORIES OF ORIGIN.

Situated a short distance offshore and within 3 miles west of the mouth of the Sabine are two small oval areas less than a mile in longer diameter, in which the water is always relatively smooth. The approximate size and location of these areas are shown on the accompanying map (fig. 6). This peculiarity of the water in these areas, particularly in the western of the two, has been known to local pilots, fishermen, and others for many years. It is stated on reliable authority that no matter how heavy the sea may be on surrounding portions of the Gulf, within these restricted areas, it never breaks, and this fact is constantly taken advantage of by coasting vessels, which find here a safe anchorage during storms. The commonly accepted explanation of this peculiarity, among sailors and others, is that oil coming from submarine springs spreads over the surface of the water for a short distance around the vents, and thus prevents the waves breaking. So widespread is this view that accounts of these "oil ponds" are common in the literature relating to the use of oil on the water during storms at sea. It does not appear, however, that any oil film has ever been observed on the surface of these portions of the Gulf, and the commonly accepted explanation merely rests on an inference from the observed effect of oil artificially applied.

Dr. W. B. Phillips[b] accepts the facts above stated, but offers another explanation, namely, that the quiet water is due not to oil, but to the presence upon the Gulf bottom of very fine mud containing a lage amount of decayed organic matter which is stirred up by the waves and produces the same effect as oil spread upon the surface. Quoting Doctor Phillips's words:

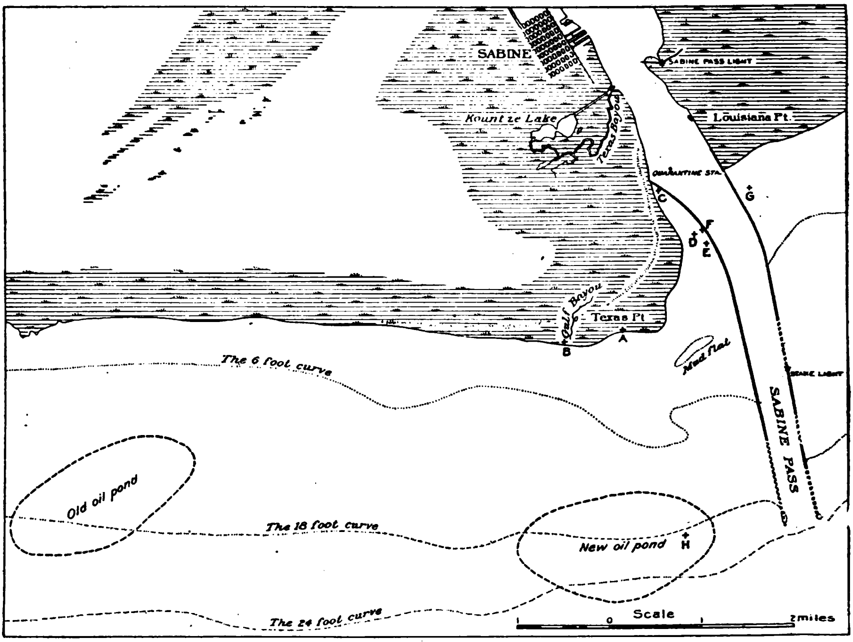

FIG. 6.—Map of Sabine Pass, showing location of so-called oil ponds.

"The true explanation of the so-called oil pond appears to be as follows: The bottom of the sea there is composed, for the most part, of a thick black mud in which are embedded various animal and vegetable remains. Under the incipient decomposition that is nearly always in progress in such material, substances of a more or less oily nature are formed. The absorption or segregation of oil by means of certain diatoms may also have contributed to the presence of oily substances in the ooze. When this mass becomes stirred up by wave action and diffuses itself through the water, rising even to the surface, the roughness of the water is affected in a manner comparable with the action of oil. The soundings in the so-called oil pond, according to chart No. 203 of the United States Coast and Geodetic Survey, vary from 4 to 16 feet, while outside of the shallow water the depth increases to 20 and 25 feet, the 5-fathom curve lying about a mile to the south. The oil-pond area is then a sort of terrace, the bottom of which is soft black mud and ooze. At one place on the chart a rocky bottom is marked, but this lies outside the area known as 'the pond' and is between the present pond and the site of the old pond. Waves beating upon a terrace laid in material which from its very nature is more or less oily, or contains substances which would act in a manner comparable with that of oil, would seem to present the true explanation of the calmness of the area under discussion."

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[a] Reprinted from Bull. U. S. Geol. Survey No. 212.
[b] Texas petroleum: Bull. Univ. Texas No. 5, July, 1900.

It may be said in objection to this explanation that these areas of calm water do not appear to be intimately connected with any peculiarity in the topography of the Gulf bottom, or with the character of the material of which it is formed, or with the special abundance or peculiarity in the forms of animal or vegetable organisms living there. On the contrary, precisely the same conditions in all these respects characterize the Gulf coast for many miles, and if they are sufficient to produce calm water at one or two points they should produce the same effect along the entire coast An essential feature which must be accounted for by any satisfactory explanation is the extremely local character of the quiet spots and their persistence for many years, practically unchanged, although it appears that the location of the western area was permanently shifted some distance to the east during the great storm of 1878.

Whether or not these areas of calm water are due to the presence of oil must for the present, therefore, remain an open question; but, at any rate, some other explanation than that offered by Doctor Phillips must be found. Although the presence of oil in these so-called oil ponds has not been proved, there is no question of its occurrence in the immediate vicinity. At various points along the west jetty at the mouth of Sabine River oil globules may be obtained by stirring the mud to a depth of 6 to 10 feet. This locality was examined by Doctor Phillips, and again by his assistants, and he expresses the conclusion in the report above quoted that the oil there found was derived from the Beaumont field; that it had been carried down Neches River or Hildebrands Bayou, and had accumulated in the angle between the west jetty and the shore, becoming finally entangled with the mud. The possibility of this origin for the oil at the mouth of the Sabine was thoroughly examined by the writers, and it is not believed possible that it could have been derived from such a source.

Anyone familiar with the behavior of oil upon the surface of water will appreciate the difficulties of the explanation given by Doctor Phillips. Oil tends to spread out in a thin film, in which condition it is subject to rapid evaporation, and is thus quickly dissipated. Moreover, being lighter than water and having the tendency, owing to its surface tension, of spreading in a thin film, it could scarcely sink to the bottom and become entangled in mud to the depth at which it is now found. Again, the oil is found only along the west jetty, whereas, if it had floated down the river it should be found in equal or greater quantities along the east jetty, owing to the direction of the prevailing winds and currents. Finally, while the chief attention has been attracted to it since the discovery of the Beaumont field, it is reported on good authority that the oil was observed while the jetties were being constructed, many years before it could possibly have been derived from Beaumont.

The conclusion appears inevitable, therefore, that the oil is either indigenous in the mud forming the Gulf bottom, or, if derived from any extraneous source, that this source is the underlying beds. It is of course possible that it has been formed in place, through chemical or organic agencies, chiefly by living diatoms, as suggested by Doctor Phillips in the report above quoted. While he does not state his conclusion explicitly, he apparently inclines to the view that while the oil actually found is derived from the Beaumont field, oil of similar character may be secreted by the diatoms living in the mud. In order to determine this point, numerous samples of mud were collected at various places in the vicinity, from the surface, at different depths of water, and from a considerable depth below the surface. These were submitted for chemical and microscopical study to Dr. Harold J. Turner, of Johns Hopkins University. Doctor Turner's results are here given in full:

EXAMINATION OF MUD FROM GULF OF MEXICO.

"In the plasma [a] of certain species of diatoms numerous minute globules of oil are contained. They are distributed irregularly through the body. In the genera *Navicula* and *Pleurosigma* the globules are relatively large, and in *Navicula* most numerous. Under the microscope the globules of oil in the body of the diatom strike the eye at once by their great refraction of the light. The fatty nature of the globule is shown by its immediately turning dark upon staining with osmic acid, as was first pointed out by Schultze. [b] Diatoms are plants, and build up their organic structure under the influence of light from carbon dioxide and water. Starch and sugar are not formed, and it may well be that the oil is the first product of assimilation. Both Lüders [c] and Pfitzer [d] have observed that the fatty oil is accumulated especially at the time when the cells are existing under unfavorable conditions, as when they are contained in a basin of water in a room. When the water in the basin is renewed, and consequently the oxygen also, the oil is largely reabsorbed in the plasma of the diatom.

"In a recent investigation Kraemer and Spilker [e] have suggested that in the oil of diatoms petroleum may have its origin. They worked upon some material to which the name 'Seeschlick' (sea slime, ooze) has been applied. The material occurs in Uckermark, a subdivision of Prussia, north of Berlin. It underlies a peat bog and reaches the depth of more than 40 feet. To the hand it has a somewhat fatty feel. The mass contains 90 per cent water, which dries out slowly in the air. The material is rich in nitrogen, containing more than 3 per cent; and it is used both for fertilizing purposes and for the extraction of ammonia on a large scale. Under the microscope the ooze is seen to consist principally of diatoms, such, for example, as species of *Navicula*, *Melosira*, and *Pleurosigma*. Upon extracting the dried mass with hot benzine and crystallizing the material obtained from alcohol, a crystalline product melting at 75° C. is obtained. The residue, insoluble in alcohol, closely resembles paraffin oil obtained from certain petroleums.

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[a] E. Pfitzer, Bau und Entwicklung der Bacillariaceen, in J. Hanstein's Botanische Abhandlung, 1871, p. 33.

[b] Schultze, Bewegung der Diatomen, p. 374.

[c] Lüders, Beobachtung, u. s. w., p. 42.

[d] Pfitzer, Hanstein's Botanische Abhandlung, p. 34.

[e] Ber. Deutsch. chem. Gesell., vol. 32, 1899, p. 2940.

"By treating the ooze with 5 per cent hydrochloric acid (by which operation about one-half of the weight is lost as hydrocarbons, organic acids, etc.) and drying the insoluble portion, there was obtained on the average 3.6 per cent of diatom wax which could hardly be distinguished from ozocerite. It had a black color, a fatty luster, an asphalt fracture, melted between 50° and 70° C., and contained 0.97 per cent sulphur. Upon combustion it yielded 73.5 per cent carbon, 11.2 per cent hydrogen, and some oxygen. By investigating various specimens of ozocerite Kraemer and Spilker found that the diatom wax had closely similar properties, and they argue a common origin of the two. They suggest that the diatom is an agency in the formation of petroleum. The minute oil globules contained in the plasma of the diatom may be the origin of some petroleum.

"The region where is found the mud yielding the oil is on the margin of the Gulf of Mexico near Sabine Pass, immediately west of the west jetty and about 3,200 feet from its landward end, at the point marked 'F' on the accompanying map (fig. 6). The mud is thick and black. It appears to be composed of thoroughly macerated organic matter mixed with grains of silica. The shells form only a very small part of the whole. By stirring the mud to a depth of 3 to 4 feet abundant globules of oil, 1 to 4 mm. in diameter, rise to the surface and there break. It appears that the number of globules increases as the depth of the mud which is stirred becomes greater. The strata of mud upon which rests the mat upon which the jetty is constructed yield the most oil. The oil is not equally distributed, but is more abundant at some points than at others, being most abundant at the edge of the mat. It is reported that the workmen observed oil in the mud at the time the jetty was constructed.

"A sample of 2 cc. of this oil was collected under great difficulties, as the globules break on reaching the surface of the water. From it the oil was extracted with ether. Upon evaporation of the ether a thick black oil was obtained, possessing a not disagreeable odor, and much thicker than crude Beaumont oil. An attempt was made to compare it with Beaumont oil by violently shaking a sample of the latter with mud and sea water at intervals for three days, distilling with steam for two hours, and extracting with ether. The residual oil still possessed its characteristic odor, though not so marked, and it was not as thick as the oil collected from the mud. It did not seem possible to identify the oil from the mud with the Beaumont oil.

"The various samples of mud were carefully examined for oil. Each sample was repeatedly extracted with redistilled ether. The extracts, after evaporation of the ether, yielded a very thin film of a greenish-yellow residue containing sulphur. A blank determination showed that the method was capable of extracting a globule of oil about 3 mm. in diameter after it had been thoroughly worked into the mud. Two samples, Nos. 109 and 114, yielded traces of oil. The other samples were free of oil. The presence of sulphur is not unusual in dark-colored muds, arising as it does from the decomposition of organic material.

"The salt-water diatoms multiply very rapidly, and their shells would in time fill up the tropical seas, were it not for their enemies, which devour them in enormous numbers. The region in the Gulf of Mexico whence were obtained the samples of muds is not especially favorable for the accumulation of diatoms, judging from the number of them actually found in the mud. Many species of diatoms belonging to the various genera, namely, *Navicula*, *Pleurosigma*, *Rhoicosigma*, *Mellosira*, and *Coscinodiscus*, were found in the samples. The species of *Navicula* and *Pleurosigma* are the most numerous. Of the entire mass only a very small fraction consists of diatom shells. The mud consists largely of thoroughly macerated organic material mixed with grains of silica. A 10 per cent hydrochloric acid produced just a slight effervescence.

"The microscopical and chemical examination of the samples of mud gave the following results:

No. 105. Collected 6 feet below the surface, which was covered by 4 feet of water at mean tide, on beach, at point marked "A" on map. Few whole diatom shells; no living diatoms; no oil.

No. 106. Collected 30 feet below surface at same place as No. 105. Few pieces of broken shells; no living diatoms; no oil.

No. 107. Collected 18 feet below surface and 17½ feet below tide level, on beach, at "B." Same as No. 106.

No. 108. Collected 30 feet below surface, at same place as No. 107. Same as No. 107.

No. 109. Collected from surface, uncovered at low tide, west of west jetty, Sabine Pass, about 600 feet from landward end, at "C." This sample consists of two kinds of mud, one black, the other greenish-yellow in color. In the dark-colored mud the shells were numerous. The greenish-yellow mud was plentifully supplied with diatom shells and contained living diatoms of the species *Navicula* and *Pleurosigma*. The entire sample of 115 grams yielded a trace of oil. The sample was from mud showing oily film on surface.

No. 110. Collected 5 feet below surface, in same place as No. 109. Many shells; no living diatoms; no oil.

No. 111. Collected 6.8 feet below surface, exposed at extremely low tide, 200 feet west of west jetty, 3,500 feet from its landward end, at "D." Few shells; no diatoms; no oil.

No. 112. Collected 6 feet below surface, which is covered at mean low tide, 300 feet west of west jetty, 5,500 feet from its landward end, at "E." Same as No. 111.

No. 114. Collected 4 feet below surface, covered by 2 feet of water, at mean low tide, west of west jetty, 3,200 feet from its landward end, at "F." Shells no more numerous than in No. 111. 100 grams of mud yielded a trace of oil.

No. 115. Collected 10 feet below the surface, which is covered by a few inches of water at low tide, 250 feet east of east jetty, 50 feet from edge of marsh, at "G." Few whole shells; no living diatoms; no oil.

No. 116. Collected at surface, same place as No. 115. Few shells; living diatoms present; no oil.

No. 117. Collected 2 feet below surface covered by 9½ feet of water, 6,000 feet west of west jetty, at "H." No living diatoms; some shells; no oil.

"Diatom shells are found in all the samples, but they are not abundant in a single one. They are, however, more abundant in samples Nos. 109 and 116 than in any of the others. Both of these samples were collected from the surface of the mud, while all the others were collected from below it. In each of the samples collected from 2 to 8 feet below the surface, i. e., Nos. 111, 112, 114, 115, and 117, a few shells are found. The shells are least abundant in samples Nos. 106, 107, and 108, which were collected from 18 to 30 feet below the surface along the shore.

"Living diatoms were found in the two samples taken at the surface, Nos. 109 and 116, but they were absent from all the samples which had been collected below the surface of the mud. The compact nature of the mud, which prevents free circulation of water and consequent renewal of the oxygen, is inimical to the existence of the diatoms.

"The samples of mud were free of oil, except samples Nos. 109 and 114. The latter is the mud from which the oil globules rise when stirred, and the occurrence of the oil in No. 109 is doubtless to be attributed to the same cause as will account for that in No. 114. The samples of mud which were collected 2 and 9 feet below the surface were free of living diatoms. The quantity of shells contained in the mud was small in comparison with the total contents of the mud.

"With these facts before us it does not seem possible to explain the occurrence of the oil in the black mud as arising from the action of diatoms. It can not be attributed to the segregation of oil by living diatoms, because of their entire absence from the mud; nor can it have its origin in diatoms buried in the mud in the past, because of the small number of shells present; and, lastly, as regards its contents of diatoms, the mud from which the oil rises is not different from the mud at various places near by, which show no traces of oil."

The results of this investigation by Doctor Turner, while not absolutely conclusive, indicate that some other source for this oil must be sought than the diatoms. Since, as shown above, it is entirely improbable that the oil was derived from Beaumont by floating upon the surface of the water; the only other source assignable is from the underlying strata. It does not necessarily follow, even if this is the case, that this region is underlain by a commercial deposit of petroleum, but the indications are sufficiently favorable to warrant thorough exploration by means of the drill. The most favorable indications are afforded within the region lying between the quarantine station and the outer end of the west jetty and thence westward for a quarter of a mile.

SEA WAX.

In connection with the so-called oil ponds may be mentioned a peculiar substance called sea wax, which is frequently found along the Gulf beach from the Sabine to Corpus Christi. This sea wax is reported to have been found in cakes as large as 6 or 8 feet in length and an inch or two in thickness. The chemical composition of this material has been determined by Dr. A. L. Watz, of Tulane University, his results being given in full by Doctor Phillips in the report above cited. This sea wax is undoubtedly a petroleum residuum or an asphaltum. The cakes have traces of concentric structure, as though the material had spread out in all directions from the source of supply at the center, where it is slightly thicker than elsewhere. The source of this material is not known, and it may have nothing whatever to do with the oil ponds, but its presence is at least suggestive and points to the existence of springs of liquid bitumen somewhere in the gulf, and to that extent supports the theory that the oil ponds are actually due to the escape at these points of petroleum from the underlying beds.

SCATTERED WELLS IN ORANGE AND JEFFERSON COUNTIES.

Several wells have been drilled near Orange, on Sabine River, but the materials passed through are not known to have contained anything unusual.

The Stillwell Company drilled three holes in the southeast corner of Joseph Grigsby league, near where Neches River enters Sabine Lake. There is here a considerable ridge, whose trend is nearly parallel to the shore of Sabine Lake. The ridge rises perhaps 20 feet above the lake, or half that much above the surrounding country. The deepest of the three

Stillwell wells reaches 1,475 feet. Small showings of oil were noted in all of the wells. The best showing was between 1,013 and 1,040 feet. At this depth strong gas pressures were encountered. Much sulphur is reported as occurring at about the same depth. A material called asphalt by the driller came up in fragments from the same depth. Nothing but clay was found between 1,045 and 1,475 feet.

Two wells have been drilled on Hildebrands Bayou, on the Grange league, one at Nederland and one near Port Arthur, all of which have been abandoned. The following section may be taken as typical:

Log of Port Arthur Oil Company's well, 2½ miles west of Port Arthur, Tex.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Blue surface clay	87	87
2	Wet blue sand	22	109
3	Dry white sand	182	291
4	Blue clay	40	331
5	Dry sand	70	401
6	Blue clay	40	441
7	Whitish-yellow wet sand	25	466
8	Dry sand	30	496
9	Hard blue clay	227	723
10	Sand with a little oil	1½	724½
11	Hard blue clay	53½	778
12	Bluish wet sand	248	926
13	Blue clay	45	971
14	Wet sand	30	1,001
15	Sand and clay	119	1,120
16	Conglomerate of sand, mud, and clay	140	1,260

At Sabine Pass four wells have been drilled within a radius of 5 miles. In general, the section shown by these wells consists of alternate beds of blue clay and sand, the heavy blue clays predominating. Three were drilled in prospecting for petroleum and the fourth for the purpose of supplying water to the hotel at Sabine Pass. The following section may be taken as typical of the four:

Log of Texas Oil Company's well, 3 miles west of Sabine Pass, Tex.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Blue and yellow sand	170	170
2	Dark quicksand	130	300
3	Blue clay	430	730
4	Blue clay with asphalt	33	763
5	Blue and yellow clay with oil at bottom	236	999
6	Sand	2	1,001
7	Blue clay	38	1,039
8	Bluish-black sand	17	1,056
9	Blue clay	2	1,058
10	Coarse white sand	77	1,135
11	Blue clay and sand	155	1,390
12	Sand, clay, and shells	96	1,486

Petroleum in small quantities showed in the lowest sand, and it is claimed there was enough gas to lift the casing a few inches. The sand was very fine and flowed easily. It filled the well casing in a few hours to a height of 300 feet.

In the German-American Oil Company's well sand was also found at about 1,400 feet. This was underlain by yellow clay and gravel to a depth of 60 feet. In the Coast Ridge well wood was found in the sand at a depth of 1,120 feet. The hotel well gave abundance of salt water at 1,061 feet.

Several wells have been drilled at Big Hill, Jefferson County, about 25 miles south-southwest from Beaumont. The hill rises in a gentle swell above the surrounding prairie and contains several thousand acres. It has a somewhat irregular crescentic outline. Mr. Kennedy, who visited the locality several years ago, gives the following account:[a]

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[a] Bull. U. S. Geol. Survey No. 212, p. 126.

> One well has been drilled on the slope of the hill at its eastern extremity. A detailed log of this well is not available, but it is known that at a depth of 350 feet rock was encountered, which continued to a depth of 1,400 feet, where drilling was discontinued. This rock, which is remarkably uniform throughout its 1,050 feet, is a light-gray crystalline dolomite. The rock is massive, but contains parallel seams, which may represent bedding planes. These have an inclination of about 7°, indicating a decided dip in the beds. Since the angle of dip is obtained from cores, its direction can not be determined, but it is assumed to be toward the east with the surface slope on which the well is located. The dolomite contains much gypsum and in places is cavernous. A few small pockets of oil were found, but for the most part the rock removed in the form of cores was entirely free from any stain or other indication of oil.

The limestone here referred to is no doubt of the same nature as that of the large masses found at Spindletop and at Damon Mound. The record has since been obtained of a second well on Big Hill, but its exact location is unknown. This well went 2,496 feet before encountering any formation characteristic of the mounds. At that depth it entered "solid gray limestone, with gypsum and some pyrite." After drilling into this rock 34 feet, the well was abandoned. A well at Winnie, a few miles to the west, found no consolidated rock to a depth of 1,600 feet.

Several wells were drilled at Hampshire, on the Gulf and Interstate Railroad, one of which reached a depth of 2,506 feet. Gas was encountered at 639 feet and again at 1,658 feet. A trace of oil was noted at about 300 feet. While the materials passed through were very similar to those above the oil rock at Spindletop, it appears from the log of this well that the beds of dense limestone, which are generally but a few inches or a very few feet thick in the first 1,000 feet, become thicker with depth. For example, at a depth of 2,275 feet a 35-foot stratum of "hard white and blue lime rock" was encountered. Nothing was found which resembled the peculiar formations of the oil mounds.

Several wells have been drilled in the vicinity of Fannett, 14 miles southwest of Beaumont. The J. P. Landrum well, 3 miles west of Fannett, is 1,191 feet deep. At depths of 900 to 1,000 feet considerable gas pressures were encountered, and there were some suggestions of oil. The beds passed through are the ordinary Coastal Plain sediments.

HIGH ISLAND.

The mound called High Island lies about halfway between Sabine Pass and Galveston. It is about a mile from the Gulf coast and on the line of the Gulf and Interstate Railroad. It is entirely surrounded by salt marsh, above which it rises nearly 48 feet, that being the elevation of its highest point above sea level. It is approximately circular and about 1¼ miles in diameter. The total area of dry ground, including a low "second bench" on the north side, is nearly 2,000 acres.

A considerable part of the surface is farmed, and the mound has long been thought desirable as a summer resort. With this thought in mind the question of water supply for domestic purposes became one of importance. There are springs both on the top and at the base. The former are strongly sulphurous and are described below. Those at the base of the mound yield salt water, accompanied by a large amount of inflammable gas. The water also carries much carbonate of lime, which it deposits at the surface in the mat of coarse grasses, thus building small dome-like elevations around each vent. In an attempt to find fresh water, more than a dozen wells were sunk in the southwest quarter of the island to depths ranging from 120 to 350 feet. In all these wells salt water was found at depths varying from 150 to 200 feet. It is stated, also, that one of these wells found salt at 300 feet.

In the northern half of the island surface wells found sulphur water, with much smaller amounts of salt than in the southern half. The Smith mineral springs, on the northwest side of the island, have a considerable local reputation for medicinal qualities. The contents of these waters are of interest on account of their connection with the rock formations, as well as for comparison with "sour waters" elsewhere, whose composition has been supposed to be in some way related to the substances which characterize the oil mounds. The following analyses were made for the owner of the springs, Mr. George E. Smith:

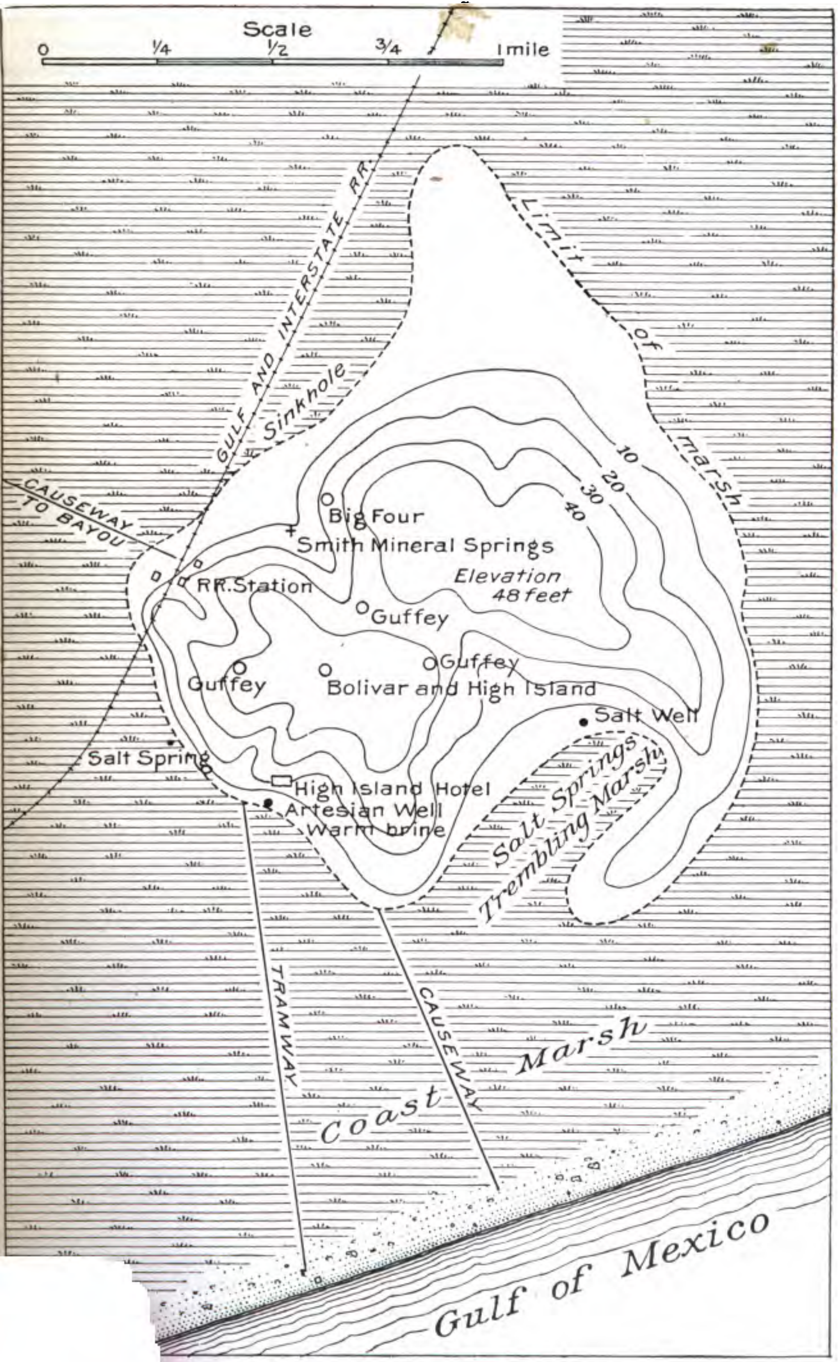

FIG. 7.—Sketch contour map of High Island.

Analysis of sample from Smith spring No. 3, High Island, Texas.

[By Prof. H. H. Harrington, of the Texas Agricultural and Mechanical College.]

	Grains to the English gallon.
Potassium chloride	1.661
Sodium chloride	5.81
Sodium sulphate	4.158
Magnesium sulphate	2.211
Protosulphate of iron	3.534
Calcium sulphate	10.808
Aluminum sulphate	3.51
Silica	1.91
Organic matter	Trace.
Total	33.602

Analysis of sample from Smith spring No. 2, High Island, Texas.

[By James Kennedy, Ph. G., M. D.]

	Grains to the U. S. gallon.
Sodium chloride	61.720
Potassium chloride	Trace.
Magnesium bicarbonate	30.479
Ferrous bicarbonate	.970
Calcium bicarbonate	15.599
Calcium sulphate	6.320
Alumina	.950
Silica	.720
Loss	.510
Total	117.263
	Cubic inches.
Sulphureted hydrogen	2.73
Organic matter	None.

In digging at one place a formation was encountered which was apparently a mass of sulphates, chiefly of iron, resulting from the oxidation of pyrite. All these springs are charged with hydrogen sulphide. The mouth of one well of this character was stopped with straw, and a year later the straw was found so thickly coated with sulphur as to resemble a solid mass of that substance.

The presence of oil was suggested by the abundance of inflammable and sulphurous gases, as well as by a superficial resemblance of the mound to Spindletop. At least six wells have been sunk to considerable depths and one to 2,600 feet. The Big Four (a test well drilled under an agreement of four companies) went 995 feet, where the water was lost in a porous rock. In a previous attempt a depth of 610 feet had been reached. A showing of oil was noted at 505 feet in the first hole and one at 972 feet in the second hole. For several hundred feet from the surface the sediments at this place contain a considerable proportion of sand, but at greater depths clay is dominant. In the deep hole of the Big Four well no fewer than 14 beds called "rock" were passed through. It can not be determined how much of this so-called rock is limestone and how much is sandstone. The former, however, is known from the data of other wells to be present in the island. The Carroll well, near the Smith mineral springs, passed through 316 feet of sands, clays, and thin rock beds, and found below these a 6-foot bed of gray limestone. At 331 feet the drill entered gypsum, in which it continued to a depth of 810 feet without passing through. This gypsum was of a white color, showing dark spots when the cores were taken out, but

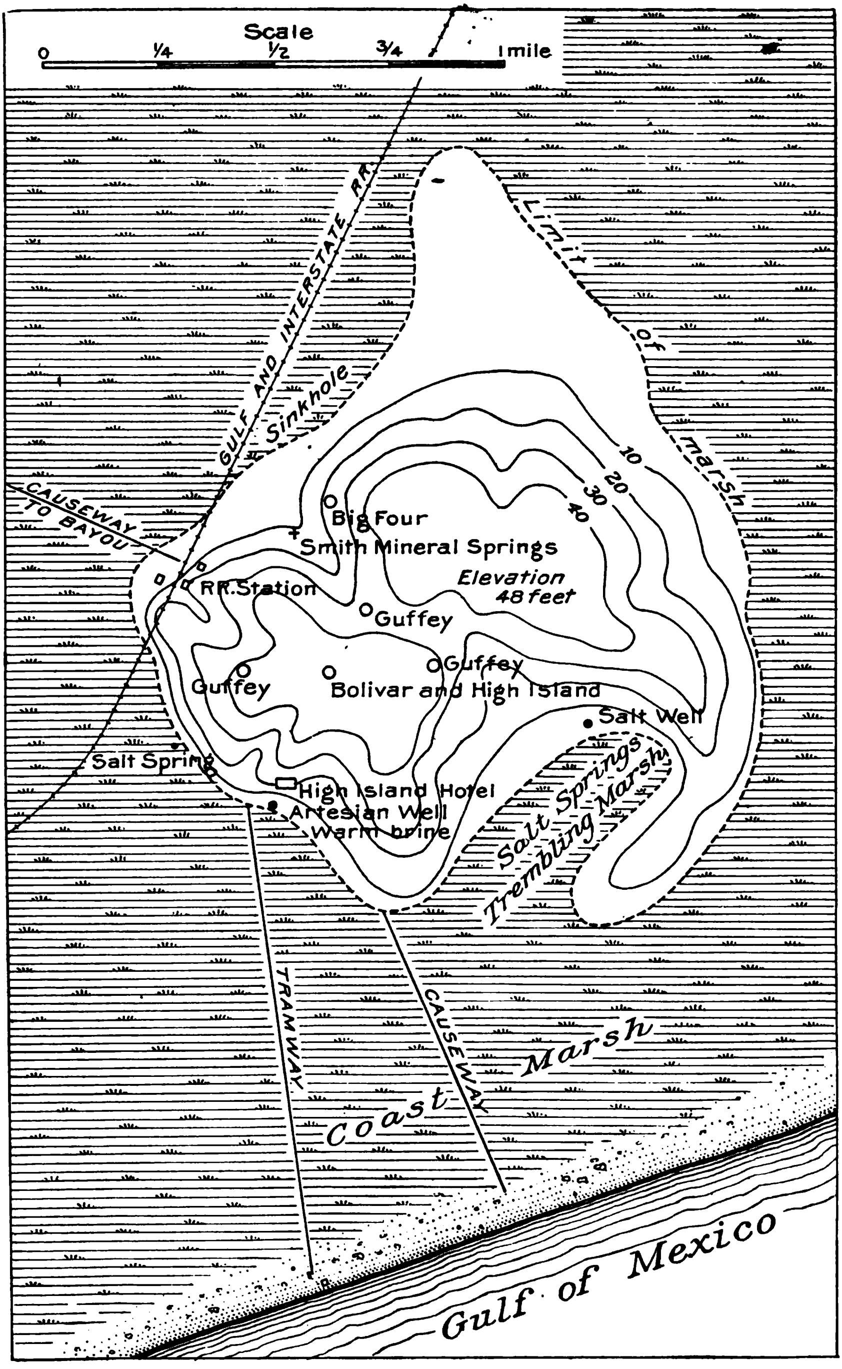

FIG. 7.—Sketch contour map of High Island.

on exposure the color of the whole became dark. The cores show crevices at least one-half inch wide, suggesting that the formation beneath the mound may contain fissures of large dimensions. One of the Guffey wells found gypsum at about 600 feet and stopped in the same substance at nearly 1,200 feet. Another passed through gypsum from 900 to 1,300 feet, where it entered pure rock salt. At 2,600 feet the salt had not yet been drilled through.

In certain other wells gypsum is found as an admixture with clay and sand. The salt reported at 300 feet is probably of the same mixed character. Hot waters are encountered, which are saline or sulphurous, or both. Sulphur compounds of lead, zinc, and barium appear occasionally in the salt and gypsum as crystals of galena, sphalerite, and barite. Slight showings of gas and oil were found at small depths, the gas being chiefly H_2S and SO_2.

The two logs which follow show the characteristic materials found in drilling:

Logs of wells on High Island, Texas.

CARROLL WELL.

[Received from Mr. Carroll.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Clay	28	28
2	Sand	8	36
3	Rock	2	38
4	Sand	8	46
5	Gumbo	8	54
6	Sand	26	90
7	Rock	1	91
8	Sand	9	100
9	Gumbo	89	189
10	Rock	3	192
11	Sand	12	204
12	Rock	1	205
13	Gumbo	26	231
14	Rock	1	232
15	Sand	9	241
16	Rock	1	242
17	Sand	19	261
18	Gravel	3	264
19	Gumbo	11	275
20	Rock	1	276
21	Sand	20	296
22	Gumbo	20	316
23	Rock	6	322
24	Gumbo	2	324
25	Rock	1	325
26	Gumbo	6	331
27	"Rock" (examined and found to be gypsum)	479	810

BIG FOUR (SECOND HOLE).

1	Clay	20	20
2	Sand with three layers of clay; struck a bowlder which followed the pipe 100 feet	206	226
3	Clay	11	237
4	Sand	45	282
5	Struck bowlder	18	300
6	Clay below gravel and shells at 350 feet	124	424
7	Hard gravel	2	426
8	Sand	6	432
9	Very hard rock; 36 hours to drill 16 inches	3	435
10	Sand	2	437
11	Hard gravel and shell	3	440
12	Hard rock	3	443
13	Gravel and shell	7	450
14	Rock; took 48 hours to drill 2 feet	2	452
15	Blue joint clay	20	472
16	Rock; 30 hours to drill 7 inches	2	474
17	Clay	3	477
18	Rock	6	483
19	Rock and clay	9	492
20	Clay	4	496
21	Clay and sand	41	537
22	Rock	2	539
23	Clay and sand; hard blue clay at 560	67	606
24	Rock	2	608
25	Sand	3	611
26	Blue gumbo	30	641
27	Shell and blue gumbo	2	643
28	Blue gumbo	24	667
29	Rock	1	668
30	Hard blue mud	124	792
31	Soft mud	16	808

Logs of wells on High Island, Texas—Continued.

BIG FOUR (SECOND HOLE)—Continued.

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
32	Shell and blue gumbo	22	830	40	Gravel	16	944
33	Very hard shells	3	833	41	Rock, gas pressure, oil indications	1	945
34	Hard rock	4	837	42	Limestone and gravel	18	963
35	Sand	60	897	43	Blue stones with mica, gas and oil signs	9	972
36	Rock	2	899	44	Mud and sand	21	993
37	Blue mud	11	910	45	Cavity or cave; lost water	2	995
38	Blue gumbo	16	926				
39	Blue gray rock, very porous	2	928				

Set 12-inch pipe at 496 feet; 4-inch pipe at 834 feet.

BARBERS HILL.

About ten wells[a] have been drilled in search of oil on Barbers Hill, in Chambers County, 20 miles south of Dayton. The hill is a roughly circular mound 20 feet or more in height and having an area of several thousand acres. Its highest part is almost flat, but its slopes, comprising the larger part of its area, are gently rolling. The surface indications which led to drilling for oil consist chiefly of the escape of gases. The appearance of the mound itself is suggestive of Spindletop, though the elevation is greater.

The principal operator in this district has been Mr. Pattillo Higgins. Before the close of the summer of 1904 Mr. Higgins had drilled five wells. It is said that several wells found indications of oil, but none have found it in paying quantities. A brown oily gum found in the Higgins well No. 5 at a depth of 738 feet has the appearance of a residuum of oil left by evaporation.

The succession of beds passed in drilling does not differ materially from the familiar series of the developed and prospective oil fields of the Coastal Plain. There are clays in abundance, with sands, gravel, and thin beds of hard limestone. In well No. 2, near the center of the island, gypsum began to appear at 557 feet, apparently as a constituent of sandy beds. From this depth to nearly 1,200 feet, where the well stopped, gypsum appears at frequent intervals, sometimes as selenite flakes, sometimes as large concretions said to be embedded in sand. A single large body of gypsum was not found, though it is not improbable that such exists at a greater depth, covering a mass of rock salt.

Mr. Higgins has preserved samples of all beds with great care. These are described in the following log:

Log of Higgins well No. 2, Barbers Hill, Chambers County, Tex.

[Description of samples kept by Pattillo Higgins.]

	Formation.	Thickness.		Total depth.	
		Ft.	*in.*	*Ft.*	*in.*
1	Soil	2	0	2	0
2	Yellow clay, blotched with red	16	0	18	0
3	Very fine yellowish sand	14	5	32	5
4	Yellow and blue variegated stiff clay	19	4	51	9
5	Reddish-yellow, very fine sand, enough clay to make it lumpy, slightly calcareous	19	0	70	9
6	Clear white silica sand	30	6	101	3
7	Variegated yellowish and blue clay	53	0	154	3

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[a] No data were obtained later than March, 1905.

Log of Higgins well No. 2, Barbers Hill, Chambers County, Tex.—Continued.

	Formation.	Thickness.		Total depth.	
		Ft.	*in.*	*Ft.*	*in.*
8	White sand	6	4	160	7
9	Light clay	15	0	175	7
10	Darker clay	2	0	177	7
11	Subangular small fragments of shale	2	0	179	7
12	Nearly white sand, medium grained	79	2	258	9
13	Blue clay	45	4	304	1
14	Fine white sand	10	0	314	1
15	Bluish limestone in small fragments	1	0	315	1
16	Fine gray sand in lumps	5	0	320	1
17	Concretionary limestone in fragments	7	1	327	2
18	Light-colored gumbo	10	4	337	6
19	White sand, medium to coarse, with black grains	17	2	354	8
20	Light gumbo	14	5	369	1
21	Coarse sand, some gumbo fragments	2	2	371	3
22	Loose yellowish sand	1	0	372	3
23	Light clay	3	4	375	7
24	Fragments of limestone, some sand	1	10	377	5
25	Light clay, few fragments of limestone	15	1	392	6
26	Light clay	3	7	396	1
27	Limestone fragments	2	3	398	4
28	Light clay	7	2	405	6
29	Loose sand, few limestone fragments as if stray	4	9	410	3
30	Loose yellowish sand	11	5	421	8
31	Loose white sand, coarse	35	6	457	2
32	Gypsum, well powdered	99	5	556	7
33	Sand and limestone fragments	11	9	568	4
34	Fine white sand	6	6	574	10
35	Gypsum as above, some sand mixed	29	5	604	3
36	Coarse silica sand, many black specks making the whole dark	5	7	609	10
37	Coarse sand, white and red grains, several gypsum concretions	6	8	616	6
38	Large concretions of gypsum (egg size) embedded in sand; some powdered gypsum shown	13	6	630	0
39	Fragments of gypsum in sand; some very fine yellow sand within this range, also some clear white sand with black grains	9	3	639	3
40	More gypsum fragments, as if from concretions	18	4	657	7
41	Dark loose sand	6	6	664	1
42	Some massive gypsum "bowlders" in sand	24	7	688	8
43	Selenite flakes and round iron-like concretions larger than peas	6	11	695	7
44	Sand loose and dark with iron-stained gravel	3	11	699	6
45	Loose sand and more iron-like nodules like peas	2	8	702	2
46	Same as 695-7 and 699-6	10	4	712	6
47	Limestone and gypsum	34	0	746	6
48	Loose gray sand	30	0	776	6
49	Gypsum flakes and sand	80	10	857	4
50	Differs little from above gypsum; little lime at places	250	8	1,108	0
51	Great gypsum concretions	7	0	1,115	0
52	Same material without the concretions, the red and yellow (as if limonite) particles more numerous	7	6	1,122	6
53	Concretions again	24	1	1,146	7
54	Clear white sand to bottom	30	0	1,176	7

VICINITY OF DAYTON.

A locality 8 miles west and a little north of Dayton attracted considerable attention for several reasons, even before oil was found in commercial quantities in April, 1905. The first occasion of interest in this locality was the obtaining of considerable quantities of gas a few feet below the surface. The surface clay in this vicinity is exceptionally impervious, and gases have therefore been retained below it which, under ordinary circumstances, would have escaped. Shallow wells and post holes filled with water show a constant bubbling up of gas. Some years ago Mr. T. R. McGowan, on and near whose farm much gas is found, dug four shallow wells for gas, one of which was 28 feet deep. At 26 feet was a layer of pyrite, partially decomposed, and beneath this an exceptionally tough bed of gumbo. Although gas had been noted at all depths, it came with much greater pressure from beneath this impervious bed. For some years Mr. McGowan burned this gas for domestic purposes. The supply was more than sufficient for the household and the larger part of it went to waste.

The second feature of interest in this locality is the rock salt discovered in deep wells drilled for oil. One of these, the Taylor-Dayton No. 1, is very near to the shallow gas wells. To a depth of 580 feet, this well showed sediments of the familiar Coastal Plain type. Moderate quantities of gas and faint showings of oil were found in certain sands. Below these were 10 feet of limestone, with a showing of oil. It is possible that this bed corresponds in its origin and nature to the oil-bearing limestone of the oil fields. The material from 590 to 799 feet was reported as solid gypsum. Beyond that the drill went 500 feet farther in pure salt, but did not pass through it. In two other wells of the Taylor-Dayton Company the salt was mixed with sand, but was said to be overlain by gypsum, as in well No. 1. Similar deposits of salt have since been found on the west side of the field.

In the winter of 1904–5 a number of wells were drilled about 1 mile south of the McGowan wells. The first of these to obtain oil was the Higgins-Paraffine No. 2, which was finished in April, 1905. Within a few months the same company sunk at least 4 successful wells, and as many more were put down by other companies. In October, 1905, the daily production of the field was between 600 and 700 barrels. The gravity varies between 17° and 23° B. In the northeastern part of the field much gas is encountered and several severe blow-outs have occurred.

The oil is found between 600 and 700 feet deep. Most of it is obtained from loose sands, and the wells in such cases are provided with strainers. In at least one case, the Higgins-Paraffine No. 6, the oil is said to be derived from "rock." The depth in this case is 619 feet. There is no accurate description of the oil rock in this well, but fragments of rock were brought to the surface by the blow-outs of the Sun No. 5 and the Morning Star. These were said to show a close resemblance to the oil rock at Spindletop. That which came from the Sun No. 5 contained much pyrite. The wells from which these fragments came yielded no oil.

This field is on the margin of "Dayton Hill," a poorly defined elevation which extends westward from Trinity River about 10 miles, having an average width of perhaps 6 miles. Its highest part is 25 to 30 feet above the surrounding country and 90 to 100 feet above the sea.

Four miles southeast of Dayton, near Trinity River, there is a low spot which has attracted attention by the abundance of its escaping gases. There are also sulphur waters and reports of small seepages of oil. Six wells have been attempted here within a very small area. Most of these have failed to get down more than a very few hundred feet. The deepest, at the time of the investigation, was the Bullard & Wilson No. 5, 670 feet.

The drilling revealed an abundance of gas, and showings of oil were found in several sandy beds. A porous limestone was found at a depth a little less than 400 feet, but it contained no oil. Strong salt water charged with hydrogen sulphide was found below 360 feet. A little sulphur came from an uncertain depth in the Bullard & Wilson well, probably from below 600 feet.

SCATTERED WELLS NEAR HOUSTON.

Several wells were drilled at Pierce Junction, 8 miles southwest of Houston. Much gas appeared both at the surface and in the wells. At least one of the wells found a showing of oil. It is said that salt was found at 900 feet, underlain by limestone. The purity of the salt is not known. The Rio Bravo Oil Company has done considerable drilling at Missouri City, 15 miles west of Houston, but without results. Reports from Blue Ridge, in Fort Bend County, indicate a curious mixture of materials between the depths of 200 and 600 feet. This mixture includes gravel, pyrite, and crystals of sulphur, in a matrix of gypsum and dolomitic limestone. On the Camp rice farm, near Alvin, the Santa Fe Railway drilled several wells, the deepest being 1,500 feet. Nothing of interest was found.

HOSKINS MOUND.[a]

In the southeastern part of Brazoria County, between Chocolate and Bastrop bayous, is Hoskins Mound. Its area is nearly 700 acres and its elevation 37 feet above sea level, or 30 feet above the plain. Three wells have been drilled here, none of which has failed to give showings of oil and gas. These occur in beds of alternating sands and clays at various depths to 800 feet. The largest showing of gas and oil was in well No. 3, in which a vigorous blow-out occurred from a depth a little less than 600 feet. A large amount of sand was expelled, together with a few barrels of oil. Thin beds of rock are found, chiefly at considerable depths. The samples of consolidated rock seen were all sandstone cemented by carbonate of lime, but thin plates of limestone are also reported.

At 610 feet in well No. 2 and at 780 feet in No. 1 thick beds of marl were found. Samples of this material were examined, and it is believed to correspond closely with the descriptions of the material which underlies the porous oil-bearing limestone in the oil-producing fields. It is sticky when wet and chalky when dry, is highly calcareous, and has little grit. It occurs here in beds 50 to 100 feet thick. As in other districts, the thick beds are poorly consolidated or perfectly soft. Where the same material has passed into limestone, it occurs in thin beds only.

The water found in the sands is comparatively fresh to depths of 800 or 900 feet. At 980 feet in well No. 2 and at 1,125 feet in well No. 1 water was struck which was described by the contractor as black, salt, sulphur water, with a very bad smell and a biting or burning effect on the tongue. It is probable that this water contains sulphuric acid.

AMSTERDAM.

At Amsterdam, on the west side of Chocolate Bayou, 7 miles north of Hoskins Mound is an elevation which is without abrupt slopes and definite boundaries except on the north side. This Amsterdam mound rises 16 feet above sea level and 10 feet above the plain.

On the east side the channel of Chocolate Bayou exposes a bed of concretionary limestone beneath 2 or 3 feet of soil. The material of the limestone horizon varies between two extreme phases. On the one hand it may appear as separate spherical concretions, often several inches in diameter. At the other extreme it is a bed of cavernous rock 2 or 3 feet thick. The concretions, when broken, frequently show wide open cracks radiating from the center. In some cases the space within is filled with clay. This limestone is of interest because of the light it may shed on the deeper porous limestones which bear oil.

Several wells have been drilled for oil—one to a depth of 1,373 feet and another to 1,499 feet. The records of these wells show occasional traces of oil and gas. Salt water continues to flow from one of them at the rate of about 1 barrel per minute.

BRYAN HEIGHTS.

This mound is in Brazoria County, 3 miles south of Velasco, and but little more than a mile from the Gulf coast. It covers an area of 300 acres and rises 30 feet above tide. The surrounding plain is about 11 feet high. This locality has received frequent mention as containing asphalt in small quantities. Jet-like or asphaltic "sea wax" has been picked up on the shore, and the soil at places contains minute grains of what is supposedly the same substance.

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[a] See note at bottom of page 138.

Seven wells were drilled for oil before the autumn of 1904. The drilling of one of these resulted in an enormous flow of gas, the chief constituent of which was hydrogen sulphide. The initial flow was estimated at 6,000,000 cubic feet daily. Other wells encountered less gas. Several wells on the heights found flows of water at depths between 450 and 500 feet. The fact that the Reed well, located on the flat on the northwest side, found a similar water supply at 611 feet has been taken by some to indicate a dip of the beds toward the edges of the mound. There is no reason, however, for believing that the beds have more lateral continuity at this place than elsewhere in the Coastal Plain. Correlations and inferences as to structure from the present well data are therefore not warranted.

Far the larger part of the formations passed in drilling are clay. Sand, gravel, and limestone appear occasionally. A number of samples have been preserved, but there is no record of the depths from which they were taken. Among these was found a gypsiferous white marl of the same nature as that found at Hoskins Mound. Another sample called "oil sand" is a purely crystalline limestone of the yellow, sugary appearance shown by many of the Spindletop samples. The sample was soaked with oil and is believed to represent a formation corresponding to the oil-bearing rock at Spindletop. This does not imply that it contains oil in commercial quantities.

Sulphur is mentioned as occurring at or below the oil horizon, and gypsum is said to be found below that depth. Samples examined showed these two substances as parts of the same fragment. There is every reason to think that the characteristic materials noted in other mounds occur here in their usual order.

The Home well yields small quantities of a strong sulphur salt water from an uncertain depth. Most of the water from the wells on the hill is as fresh as from those of the surrounding plain, on which a number of artesian wells have been sunk. Some of these wells near Brazos River, within 10 miles of its mouth, are more than 1,000 feet deep, and the water is sufficiently fresh for domestic use. A number of others from about half that depth yield smaller quantities of better water. The water of one of the deep wells at Surfside is said to have a temperature of 104°. The artesian well at Velasco is 1,060 feet deep and the water flows slowly from a 4-inch pipe. It is accompanied by gas in sufficient quantities to burn at the mouth of the well.

The following log was carefully kept by the driller:

Log of Reed well, Bryan Heights, Brazoria County, Tex.

[By J. F. Frederickson, driller.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Black surface (asphaltic specks)	30	30
2	Yellow clay	12	42
3	Quicksand	20	62
4	Yellow clay	25	87
5	Black clay	5	92
6	Black clay with reddish spots of "decomposed iron"	70	162
7	Black clay with minute white shells	27	189
8	Quicksand	21	210
9	First sign of gas in blue quicksand	16	226
10	Black clay with "decomposed lime and iron"	18	244
11	Black clay and shale	3	247
12	Black shale and sand	28	275
13	Black shale	55	330
14	Black shale with some gravel. At 365 feet were 4 inches of rock, very hard.	15	345
15	Soft black clay with "decomposed iron"	60	405
16	Soft blue clay with yellow clay mixed	62	467
17	Yellow clay, sand, and shale	82	549
18	Oil sand, pebbles, and shale; very coarse	8	557
19	Yellow clay, sand, and shale	30	587
20	Hard rock, probably sandstone	2	589
21	Oil sand, large pebbles, some oil	2	591
22	Gravel and flint	4	595
23	Black clay with shale	2	597
24	"Flint;" twisted off pipe here	1	598
25	Pipe dropped suddenly 13 feet after drilling 2 days on a very hard rock	13	611

KISER HILL.

Two miles northwest of the town of Columbia, Brazoria County, is Kiser Hill, an irregular elevation which has a height of about 30 feet above the surrounding plain. On its southern half, at less than half that elevation, four oil wells have been drilled. One of these, No. 2, has made the place known by producing, for sixteen months, by natural flow, a good lubricating oil at the rate of about 5 barrels per day. In the midst of that period the market for the oil stopped. The well continued to flow until a part of the casing was removed. The oil came from a depth of 480 feet, from a material reported as "oil sand," but samples of this were not seen. A specimen of rock taken from 364 feet in the same well and said to have contained oil, with much gas, was found to be a highly porous limestone. There were other showings of oil, at various depths, from 89 feet to 835 feet. Small blow-outs occurred at various levels, and a little gas was found as deep as 1,050 feet in well No. 3.

Sulphur is reported from various depths, always in connection with "rock," and frequently in the form of small crystals. Pyrite is likewise abundant. A rock at the bottom of well No. 4 (760 to 812 feet) is called a "black limestone with soft streaks." A small core was obtained from one of the "soft streaks" and found to be a friable sandstone, containing small veins of salt. Similar cores are said to have contained crystalline sulphur.

Water was found under strong artesian pressure. Well No. 1 continues to flow, the water being accompanied by considerable gas. The slow and long-continued flow of the oil from well No. 2 was more like the quiet overflow due to artesian pressure than the spasmodic gushing due to gas pressure.

The logs of wells Nos. 1 and 2, given below, are representative of the field:

Logs of wells at Kiser Hill, Texas.

WELL NO. 1.

[Received from Mr. John Underwood.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Similar to well No. 2; good showing of oil at 388	388	388
2	Alternating sand and clay	70	458
3	Blue shale with sand below containing good show of oil	20	478
4	Sand	20	498
5	Gray rock	2	500
6	Material not mentioned; it contains gas in large quantities, with occasional globules of oil	5	505
7	Rocks, shells, and wood, with showing of oil	5	510
8	White rock saturated with oil	2	512
9	Gray rock impregnated with something yellow, either oil or sulphur, and containing black particles	25	537
10	Blue clay	7	544
11	Rock, sandstone, or limestone, not determined	4	548
12	Black clay	16	564
13	Gray rock with pyrite and strong gas pressure	12	576
14	Blue clay with strong gas pressure	8	584
15	Gray limestone with sulphur and strong gas pressure	4	588
16	Very fine loose sand with oil alternating in thin layers with rock; strong blow-out of gas at 603	28	616
17	Soft rock with some sulphur	48	664
18	Black rock called limestone. The water was lost at this place and the hole abandoned	16	680

No oil was obtained from this well, but its showings were better than those of any other well at Kiser Hill.

Logs of wells at Kiser Hill, Texas—Continued.

WELL NO. 2.

[Received from Mr. John Underwood.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Soil	2	2
2	White clay	8	10
3	Red clay	15	25
4	Sand	1	26
5	White clay	34	60
6	Sand with streaks of clay	45	105
7	White clay	14	119
8	The same, very hard	15	134
9	Blue clay	16	150
10	Sandstone	1	151
11	Clay and sand alternating	59	210
12	Sandstone	1	211
13	Blue clay	9	220
14	Sandstone, limestone, some shells, pyrite, and sulphur crystals	2	222
15	Blue clay	23	245
16	Blue limestone, very hard, containing sulphur crystals, and some pyrite	69	314
17	Sand and shells	6	320
18	Blue clay	20	340
19	Sand showing some oil	6	346
20	Limestone; set 6-inch casing here	1	347
21	Material not given	7	354
22	Blue clay	8	362
23	Sand with some showing of oil	2	364
24	Blue porous or cavernous limestone (specimen seen), blow-out of gas and oil	6	370
25	Clay	6	376
26	Oil sand	4	380
27	Clay	21	401
28	Hard limestone, mostly shells	1	402
29	Compact sand, small blow-out at 436	34	436
30	Hard clay	22	458
31	Oil sand, good lubricating oil found at 480	32	490
	Rock.		

The water was lost in the porous limestone between 364 and 370 feet. From the oil sand struck at 476 feet, the well filled up to a depth of 160 feet while shut down for a few days. This well produced lubricating oil by natural flow for sixteen months. A part of the casing was then removed and the flow stopped.

DAMON MOUND.

This elevation, in the northwest corner of Brazoria County, is one of the most conspicuous topographic features of the Texas Coastal Plain. It rises 83 feet above the surrounding level plain, which is itself about 57 feet above the sea. The mound has an area of nearly 4 square miles, and its surface is diversified by minor hills and valleys. Erosion has been active, and the valleys are in part due to this cause. To what extent the minor inequalities of elevation are due to the same agencies which uplifted the whole mound is uncertain. From the great variation in the formations revealed by the drills, it is highly probable that the subordinate elevations are in part due to constructional agencies.

Some reputation attaches to Damon Mound on account of the "sour dirt" or "vitæ ore" which was in former years taken from its surface in carload lots and sold for medicinal purposes. This material is the soil of the island, which, in certain spots on the west side, is impregnated either with sulphur resulting from the decomposition of escaping sulphurous gases or with various salts similar to those dissolved in the waters of Sour Lake and High Island. As an indication of the geologic constitution of the hill, the mineralized soils of Damon Mound may be regarded as the equivalent of the sour waters of High Island.

Up to September, 1904, four deep wells had been drilled for oil, and a fifth was being drilled. The logs of these wells are very different. That of the Guffey No. 1, at the west base of the mound, showed sand, gravel, and clay in various stages of consolidation, and also some thin beds of limestone. The drill went down 1,097 feet and discovered nothing distinctive, unless it be a few masses of wood and a 17-foot bed of "loose dirt and sulphur." This last was reached at 729 feet. Its depth is not believed to have any significance for purposes of correlation. It is evidently an occurrence of the same nature as may be observed almost anywhere in the Coastal Plain, where hydrogen sulphide or sulphur waters rise through the uncompacted sediments. The sulphur, like the porous bed which contains it, may have very small lateral extent, and, a short distance away, beds either higher or lower may have the same character.

The Damon Mound Oil and Pipe Company's well, on the eastern slope, was drilled in very different material. After 260 feet of clay, a limestone 70 feet thick was found. Then came 200 feet more of clay, followed by 650 feet of limestone. Below this was 50 feet of sand and clay, the only sand in the section of 1,230 feet, whereas the section of the Guffey No. 1 was more than half sand.

The Herndon well, east of the center of the mound and near its highest part, encountered the materials which are most characteristic of the similar mounds found elsewhere on the Coastal Plain. One hundred and seventy-one feet of gypsum were passed between the depths of 378 and 549 feet. In the next 30 feet the gypsum was mixed with sulphur. After 8 feet of coarse sand the drill entered salt at 587 feet, and stopped in the same material at 1,160 feet.

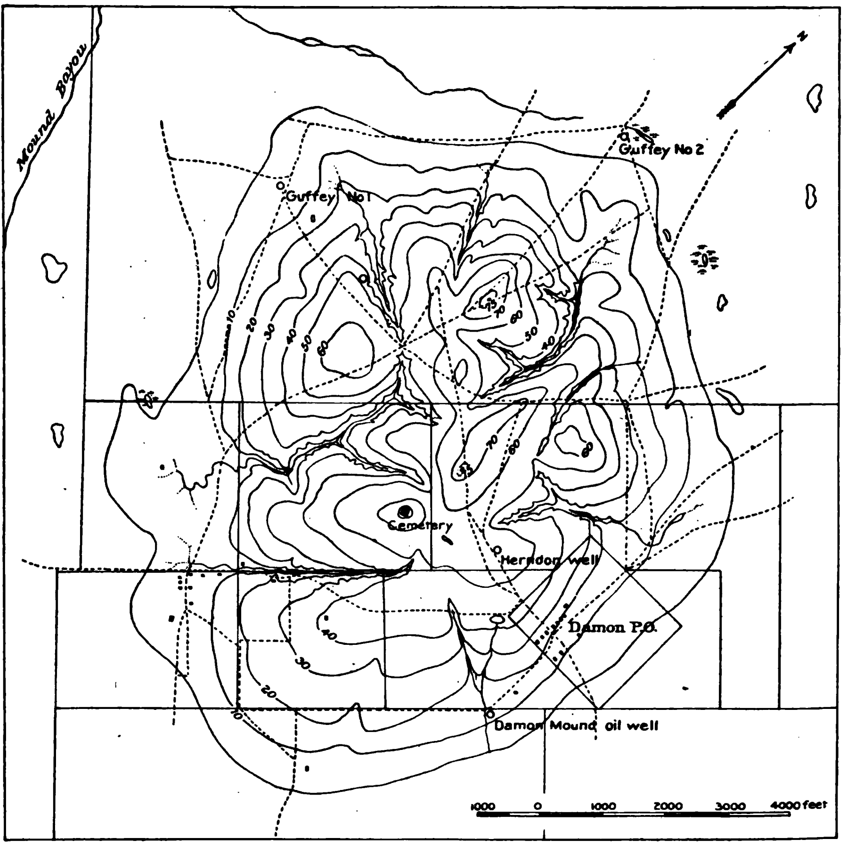


FIG. 8.—Sketch contour map of Damon Mound.

The well which was being drilled by Mr. Mulcahy on the southern slope of the mound when the district was visited in August, 1904, had reached at that time a depth of 206 feet. Fully three-fourths of that depth had been drilled in solid rock. A specimen taken from 138 feet was of hard blue cavernous limestone. Some selenite crystals were found less than 20 feet from the surface.

Limestone of a warty and cavernous appearance comes to the surface on the eastern slope. It was at one time quarried, and was shipped long distances. The horizon of this stone was no doubt calcareous from the time the sediments were laid down, but the body of limestone, as now known, is probably largely concretionary. As at Amsterdam, there are gradations between isolated concretions and large cavernous bodies.

Most of the shallow-well waters of the mound are sufficiently mineralized to have a distinctive taste, but the waters from various parts of the area differ. That which comes from a depth of 206 feet in the Mulcahy well is strongly sulphureted and contains little or no salt.

Two logs which show the distinctive geologic features of the mound are here given:

Logs of wells at Damon Mound, Texas.

HERNDON WELL.

[Elevation 140 feet.]

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Soil	11	11	7	Blue shale	19	165
2	Red clay	35	46	8	Shells and fine gravel	6	171
3	Blue clay	36	82	9	Gpysum	378	549
4	Sand	14	96	10	Sulphur and gpysum	30	579
5	Blue shale	46	142	11	Very coarse loose sand	8	587
6	Lime rock	4	146	12	Salt	573	1,160

DAMON MOUND OIL AND PIPE LINE COMPANY'S WELL.

[Elevation 100 feet.]

1	Clay	260	260	4	Limestone	650	1,180
2	Limestone	70	330	5	Sand and clay	50	1,230
3	Clay	200	530				

VICINITY OF OTTINE.

Over a considerable area, which includes parts of Gonzales, Wilson, and Bexar counties, there are frequent indications of gas and oil. The vicinity of Ottine, Gonzales County, possesses considerable interest on account of its mud volcanoes and the drilling which has been done in search of oil.

Ottine is surrounded by a rolling country, through which runs the deep valley of San Marcos River. The channel at this place is 96 feet below the level of the town. A terrace about 50 feet above the river is at places about a mile wide between bluffs. About halfway down from this terrace to the river is a newer terrace, which, in the vicinity of Ottine, is several hundred feet wide. At a still lower level the river has at places a very narrow flood plain.

It is on the lower terrace that the mud volcanoes are found. Some are now active, while dry rounded knolls appear to represent extinct ones. There are other rounded lumps as much as 5 feet high and 30 or 40 feet in diameter, with abrupt slopes meeting the flat surface of the terrace in such a manner as to give to the elevations very definite outlines. Some of these are very wet; in fact, water may be seen oozing from their tops, accompanied by bubbles of gas. The surfaces of such mounds are covered with vegetation, which forms a mat. Beneath this surface is a semiliquid quaking mass. A man standing on the top and supported by a plank may shake the entire mound. While the material of these mounds and of the more typical mud volcanoes with craters is generally mud, it is frequently mixed with sand.

The gas to which these phenomena are due also comes up copiously from the bed of the river and causes boiling pools in the sands along the river banks. It is abundant to a depth of 900 feet in the wells drilled for oil. These phenomena indicate that the gas does not result entirely from organic matter recently incorporated in the alluvial deposits. The connection of the mud volcanoes with such deposits is probably due to the fact that the gas escapes without notice through the sandy soil of the back country. Through the impervious covering of the old flood plains, however, gas must escape at isolated points where it can force a passage. In so doing it may enlarge the conduit by carrying material to the surface.

Nine wells have been drilled to various depths within 3 miles of Ottine. The Putnam well, beside San Marcos River, is 1,176 feet deep. The records of the several wells show a great preponderance of sand over other materials. Some clay was found not far below the surface. Below that, one well showed no clay and the others showed different amounts, suggesting that the deposits are in lenses, or that the same bed varies in character from place to place. Beds of rock from a few inches to several feet in thickness were numerous. Much pyrite was encountered, that at small depths being frequently decomposed, giving rise to "sour dirt."

While gas was found at frequent intervals, showings of oil were of rare occurrence. A small showing was supposed to be found at 200 feet in the well drilled by Mr. J. A. Otto west of the town, and probably also in his first well, located on the west side of the river. Small quantities of oil were found at shallow depths in wells on Mr. R. Wohlfahrt's land, 3 miles east of Ottine. A few gallons of oil coming from a depth of 82 feet were dipped out of a dug well. This led to drilling, but without success. One well reached a depth of 1,004 feet, but found no oil below 80 feet, except a faint showing at about 500 feet. A good artesian flow of water was found at about 550 feet. Half a mile to the west the Ottine Oil Company put down a well, getting a powerful artesian flow from about the same depth. The flow from this well is estimated to be at least 10 barrels per minute. The water from both artesian wells is slightly sulphurous. Some gas accompanies the water. In the Wohlfahrt artesian well the gas is said to have made its appearance several weeks after the completion of the well.

VICINITY OF SAN ANTONIO.

Small quantities of oil at shallow depths are common in the vicinity of San Antonio. Six and one-half miles southeast of the city are three wells belonging to Mr. George Dullnig, which have for some years produced a good lubricating oil for the local market. The oil is pumped only occasionally. It is estimated that the three wells together might be made to yield one barrel per day. These wells have depths of 265, 300, and 900 feet, respectively, the first yielding its oil from a depth of 235 feet and the others from 300 feet. Little is known of the materials passed through in drilling, but the oil is contained in a marly sand covered by blue clay. A few similar wells in the same vicinity are owned by the San Antonio Oil Company. Artesian wells in the city of San Antonio find a stratum at about 500 feet which in nearly all cases shows oil. Eight miles northeast of San Antonio, and 10 miles southwest, on Leona River, heavy oil has been found at small depths in quantities similar to those of the Dullnig wells.

SUTHERLAND SPRINGS.

This locality in Wilson County abounds in sulphur springs, and contains certain other features which have attracted the attention of oil investors. These include escapes of gas from the ground and an occasional oily film on the water of some of the springs. The most significant occurrence is that of small quantities of oil in wells drilled for water. The usual depth at which such showings have been noted is 80 to 100 feet. It is said that a number of wells drilled for water were abandoned on account of the taste of oil. Small quantities of the oil have been brought up from the wells and used among the farmers for lubricating purposes.

Cibolo River, at this place, has a valley several miles in width. Its immediate channel is cut 30 feet or more below the flat bottom of the valley. It is along the steep banks of the river that the largest sulphur springs occur. Their waters color the river a milky green for some distance. On the valley floor, at least half a mile from the river, are the "sour springs," which have a faint sulphur taste mingled with a slight sourness, due probably to the presence of sulphates.

On the old alluvial plain are certain so-called "bogs," which resemble some of the soft mounds found among the mud volcanoes near Ottine, except that these are not elevated. They are composed of a soft quaking mire, always wet, apparently by the rise of spring waters.

The narrow, dry channel of Alum Creek is cut about 20 feet below the main valley bottom, or 40 feet below the dissected sandstone upland. The rock walls of this gorge and the sands in its bottom are abundantly incrusted with the materials left by the evaporation of spring waters. There are layers of pure sulphur and of the sour salts, presumably sulphates. A brown loam taken from the bottom of the channel is intensely sour, resembling the "sour dirt" formerly shipped from Damon Mound.

Five wells have been drilled for oil within a strip about 3 miles long. The Pipkin well, whose log is given below, found showings of oil at depths of 415, 775, and 1,352 feet. In the Hobbs well, located in the vicinity where oil appeared in the water wells, oil was detected at 80 feet and again at 350. Gas appeared in the Pipkin well at various depths. In the Adams & Wolf well, a blow-out occurred at 140 feet. Strong sulphur water like that from the springs is flowing from the Pipkin well at a rate of at least 1 barrel per minute. As flows were encountered at three horizons below 970 feet, the depth from which this water comes was not ascertained.

The exposed sandstones of this vicinity show some considerable dips, but the details of structure have not been worked out.

Log of Pipkin well (American Mineral Company), Sutherland Springs, Tex.

[Kept by P. E. Pannewitz.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Soil	14	14
2	Coarse white sand, with flowing water and gas	3	17
3	Fine gray sand	13	30
4	Soft gray rock	2	32
5	Black gumbo and gravel	16	48
6	Soft gray rock	4	52
7	White sand	13	65
8	Hard gray rock containing pyrite	6	71
9	Coarse white sand, with flowing sulphur, water, and gas	19	90
10	Gray sand, with pebbles and lignite	16	106
11	Soft gray rock	5	111
12	Gray sand containing wood	29	140
13	Hard gray "bowlders"	7	147
14	Gray sand mixed with shells	61	208
15	Blue gumbo	6	214
16	Soft gray rock	8	222
17	Gray sand mixed with shells	12	234
18	Hard gray "bowlders"	6	240
19	Gray sand	40	280
20	The same, mixed with lignite	7	287
21	The same, mixed with wood	8	295
22	The same, mixed with lignite	7	302
23	Gray sand	58	360
24	Hard dark-gray rock	8	368
25	Hard dark-gray clay	2	370
26	Hard dark-gray rock	1	371
27	Hard blue gumbo, very sour	2	373
28	Hard dark-gray rock	2	375
29	Dark-gray clay and sand	3	378
30	Hard dark-gray rock	2	380
31	Dark-gray clay and sand, with lignite and iron	35	415
32	Dark-gray crystallized limestone, with trace of oil	4	419
33	Dark-gray clay, with lignite, shells, iron, and flowing water	62	481
34	Hard dark-gray rock	3	484
35	Black clay, with lignite, shells, and iron	144	628
36	Hard light-blue rock, with trace of oil	12	640
37	Black clay, mixed with shells	52	692
38	Soft gray rock	8	700
39	Gray sand, with shells	34	734
40	Hard black lignite	6	740
41	Very hard dolomite	2	742

Log of Pipkin well (American Mineral Company), Sutherland Springs, Tex.—**Continued.**

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
42	Gray clay, with shells and iron	29	771
43	Soft gray rock	4	775
44	Hard black rock, porous in parts, with trace of oil	32	807
45	Black clay, mixed with shells	60	867
46	Soft dark-gray rock	8	875
47	Dark-gray clay and sand	11	886
48	Hard black dolomite containing gas	3	889
49	Gray clay, with shells, iron, and fine greensand	60	949
50	Hard dark-gray limestone	3	952
51	Black clay mixed with iron, magnesia, and shells	21	973
52	Soft dark-gray rock; flowing water of bad odor	10	983
53	Black clay mixed with iron and shells	1	984
54	Hard black limestone	1	985
55	Black clay	3	988
56	Hard black limestone	1	989
57	Black clay, with shells, iron, and magnesia	39	1,028
58	Hard black dolomite	4	1,032
59	Black clay, with shells, iron, and magnesia	18	1,050
60	Hard black rock, with shells	6	1,065
61	Dark sand, containing iron, flowing water, and gas	34	1,090
62	Soft dark rock	4	1,094
63	Dark shale	9	1,103
64	Hard black gumbo mixed with iron "bowlders"	4	1,107
65	Hard dark limestone	7	1,114
66	Dark sand	114	1,228
67	Dark sand and clay mixed with shells	2	1,230
68	Hard dark rock	4	1,234
69	Dark clay mixed with iron and shells	12	1,246
70	Hard dark rock	4	1,250
71	Dark sand	98	1,348
72	Soft dark rock	4	1,352
73	Hard dark rock, with trace of oil and flowing water	2	1,354
74	Dark sand	32	1,386
75	Dark sand and clay mixed with iron and shells	22	1,408
76	Soft dark rock	4	1,412
77	Dark sand	88	1,500

JENNINGS FIELD.

LOCATION.

The Jennings field, which produces most of the petroleum of Louisiana, is situated in Acadia Parish, about 6 miles northeast of the city of Jennings and an equal distance from Mermentau station, on the Southern Pacific Railroad. The field lies about midway between Bayou Nezpique and Bayou des Cannes, these two streams being about 4 miles apart and uniting with each other, and with Bayou Plaquemine, some 3 miles south of the oil field, to form Mermentau River. Jennings is 90 miles east of Beaumont, Tex., and 188 miles west of New Orleans. The field lies nearly 50 miles inland from the Gulf coast, and is on the outcrop of the Port Hudson (Pleistocene) formation, as mapped by the Louisiana Survey.

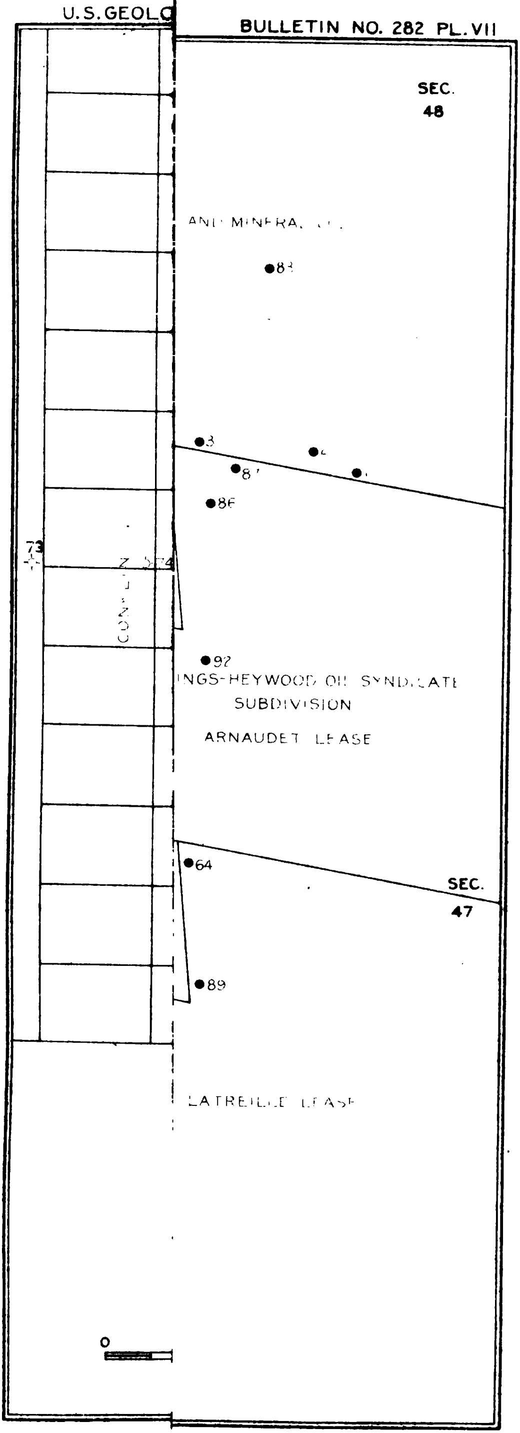
TOPOGRAPHY.

This part of the Coastal Plain is not so perfect a flat as that which surrounds the city of Beaumont, Tex. The two bayous have incised the surface of the plain to a depth of perhaps 20 feet. The beginnings of dissection by their tributaries impart to the neighboring strips of land a gently rolling surface. In addition to this relief due to stream action the Jennings field has a further elevation, probably not greater than 5 or 6 feet, which appears superficially to be of the same nature as that of Spindletop and other oil mounds of Texas. This elevation is not oval in plan or symmetrical in form, but irregular and of indefinite boundaries. The dissection of its borders by the beginnings of stream erosion makes it difficult to decide how much of its height should be ascribed to uplift and how much to erosion.

HISTORY AND PRODUCTION.

GROWTH OF THE FIELD.

Attempts to find oil in this field were induced by the escape of gas from the soil. The first drilling was by the Jennings Oil Company, but the well was ruined by an accident



THE NORRIS PETERS CO., WASHINGTON, D. C.

after six months of labor. In August, 1901, the Southern Oil Company drilled a well 1,822 feet deep. By its violent gushing of oil and sand this well showed beyond doubt that the formation encountered was an oil-bearing sand of importance. The well produced 200,000 barrels before the gushing ceased. There is no record of any sale of oil from the field in 1901, but in the following year Louisiana produced 548,677 barrels, almost all of which came from the Jennings field. In 1903 the output was approximately doubled. The production during the first half of 1904 continued at a rate not very different from that of the previous year, ranging between 2,000 and 2,500 barrels a day. On August 4, 1904, the Producers Company finished a well on the Latreille tract, on the east side of the field, which became the first great Jennings gusher. Following this success other large wells were put down in rapid succession. All but the first of the great gushers are in the Arnaudet tract, on the east side of the field.[a] The yield of these wells rapidly increased the output of the field to over 50,000 barrels a day, and for several months the rate of production did not fall below that figure. Over 6,000,000 barrels were produced in the last five months of 1904. More than 95 per cent of this oil came to the surface by natural flow from the wells finished after August 1 on the east side of the field. The small balance was pumped from the older wells.

INDIVIDUAL WELLS.

Some of the newer wells will be noteworthy in the annals of the oil industry for their large yields in short times. The Bass & Beckenstein No. 1 yielded 1,500,000 barrels in the one hundred and forty-five days from September 8 to January 31, this probably making a short-time record for the United States, though the statistics of other fields are not at hand to support this statement. The Wilkins No. 2 yielded 995,800 barrels in the eighty-two days from November 20 to February 10. It will be observed that these notable outputs do not involve daily yields from single wells much greater than 12,000 barrels, and that no well yielded, in any single day, much more than 15,000 barrels. A comparison of these figures with those of Spindletop, where initial daily capacities as great as 95,000 barrels were ascribed to certain wells, does much to emphasize the oft-repeated statement that the unprecedented gushing of the Spindletop wells was of very brief duration.

RESERVOIRS AND PIPE LINES.

To accommodate the great production of the Jennings field the tankage, steel and earthen, was rapidly increased to more than 7,500,000 barrels. Four pipe lines connect the field with the Southern Pacific Railroad at various points, and a line has been built to Atchafalaya River, a distance of 59½ miles to the east, passing through the Anse la Butte fields, 45 miles east of Jennings.

USES AND CHARACTER OF THE OIL.

Up to August, 1904, most of the Jennings oil was used for fuel by various industries within 100 miles of the field. During the summer season much of it went to the pumps employed to flood the rice lands. Some had from the outset been bought by the Southern Pacific Railroad for fuel, and after the coming in of the great gushers most of the product was used in this way. A small refinery was built at Jennings, which is able to obtain from the crude oil about 7 per cent of illuminating oil, 25 per cent cylinder oil, and 4 per cent good asphalt, suitable for roofing and roofing paint. The remaining 64 per cent furnishes lighter lubricating and neutral oils.

GEOLOGIC FORMATIONS.

WELL SECTIONS.

The character of the formations is well illustrated by the following logs. That of the Chicago-Jennings well No. 1 illustrates the character of the formations outside the field as compared with those within the productive area.

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[a] No data have been obtained since May, 1905.

Logs of wells in and near Jennings field.

GUARANTEE WELL NO. 1.

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Yellow clay	35	35	22	Rock	⅞	1,315⅞
2	Red sand	20	55	23	Clay	200	1,513⅞
3	Clay	10	65	24	Rock	½	1,516½
4	Blue sand	25	90	25	Sand	13½	1,530
5	Sand and shells (gas)	10	100	26	Clay	90	1,620
6	Coarse sand and gravel	600	700	27	Rock	⅝	1,620⅝
7	Clay	10	710	28	Clay and shells	13⅛	1,634
8	Fine gravel	10	720	29	Sand	5	1,639
9	Fine yellow sand	20	740	30	Clay and shells	46	1,685
10	Clay	20	760	31	Sand	10	1,695
11	Gravel	160	920	32	Clay	20	1,715
12	Clay	80	1,000	33	Sand (oil)	25	1,740
13	Sand	20	1,020	34	Clay	4	1,744
14	Clay	60	1,080	35	Sand and shells	10	1,754
15	Sand	40	1,120	36	Clay	20	1,774
16	Sand (oil)	10	1,130	37	Rock	2	1,776
17	Clay	20	1,150	38	Clay	10	1,786
18	....do	50	1,200	39	Sand	4	1,790
19	Sand	40	1,240	40	Clay	43	1,833
20	Clay	60	1,300	41	Sand (oil)	54	1,887
21	Sand	15	1,315				

CROWLEY OIL AND MINERAL COMPANY'S WELL NO. 3.

[Log kept by Mr. Lake Grow.]

1	Clay	60	60	10	Shells, rock, gravel, and fine sand	20	1,560
2	Quicksand and gravel	840	900	11	Shells and gumbo	32	1,592
3	Blue shale	43	943	12	Oil sand, coarse mixed with gravel and dry asphalt	95	1,687
4	Gravel	207	1,150	13	Blue shale	73	1,760
5	Blue shale	210	1,360	14	Oil sand, very hard	40	1,800
6	Gravel	50	1,410	15	Shells and blue shale	10	1,810
7	Blue shale	20	1,430				
8	Gravel	12	1,442				
9	Blue shale	98	1,540				

This well has 43 feet of screen at the bottom and 100 feet from 1,597 to 1,697.

CROWLEY OIL AND MINERAL COMPANY'S WELL NO. 5.

[Log kept by Mr. Lake Grow.]

1	Clay	65	65	11	Hard rock	1	1,501
2	Quicksand and gravel	745	810	12	Blue shale	79	1,580
3	Blue shale	90	900	13	Hard sand, no oil	40	1,620
4	Gravel and shells	160	1,060	14	Gumbo	30	1,650
5	Blue shale	120	1,180	15	Hard sand, no oil	20	1,670
6	Gravel and rock	20	1,200	16	Good show of oil (presumably sand)	40	1,710
7	Blue shale; a few inches of rock at the bottom	75	1,275	17	Hard sand, salt water	24	1,734
8	Gravel	25	1,300	18	Gumbo	6	1,740
9	Blue shale	100	1,400	19	Thin shell rock, then almost solid oil sand	80	1,820
10	Rock, hard gumbo, and shells	100	1,500				

Well drilled in April, 1904; 82 feet of screen.

Logs of wells in and near Jennings field—Continued.

CHICAGO-JENNINGS OIL COMPANY'S WELL NO. 1, 1½ MILES NORTHWEST FROM JENNINGS FIELD, ON GARROULD LAND.

[H. H. Jones, driller and contractor.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Clay	101	101
2	Sand and gravel	331	432
3	Clay	76	508
4	Sand	10	518
5	Clay	22	540
6	Gravel	10	550
7	Clay	44	594
8	Gravel	22	616
9	Gravel in clay	21	637
10	Sand and gravel	84	721
11	Gravel	19	740
12	Rock	2	742
13	Clay	17	759
14	Rock	3	762
15	Sandy clay	18	780
16	Clay	10	790
17	Gravel	22	812
18	Clay	18	830
19	Soft limestone	40	870
20	Clay and sand	20	890
21	Tough blue clay	112	1,002
22	Sand and clay	14	1,016
23	Fine blue sand	93	1,109
24	Packed sand	51	1,160
25	Sandstone	1	1,161
26	Packed sand	19	1,180
27	Rock	1	1,181
28	Sand	49	1,230
29	Clay	57	1,287
30	Rock	1	1,288
31	Clay	5	1,293
32	Rock	1	1,294
33	Clay	54	1,348
34	Sandstone with light showing of oil	5	1,353
35	Clay	5	1,358
36	Hard sandstone	4	1,362
37	Clay and shale	50	1,412
38	Blue clay	20	1,432
39	Sandy blue clay	41	1,472
40	Sand, shells, and clay, the last 3 feet hard	21	1,494
41	Blue clay	24	1,518
42	Rock	3	1,521
43	Sand	3	1,524
44	Clay with shells at bottom	50	1,574
45	Clay	163	1,737
46	Rock	1	1,738
47	Hard clay	43	1,781
48	Hard clay, hardpan with sand at bottom	66	1,847
49	Hardpan with sand streaks and clay	63	1,910
50	Streaks of clay and sand	62	1,972
51	Sand	20	1,992
52	Clay	4	1,996
53	Sand	4	2,000
54	Soft rock	3	2,003
55	Rock and clay	13	2,016
56	Rock	1	2,017
57	Sand with gas	13	2,030
58	Clay	6	2,036
59	Sand	6	2,042
60	Clay	8	2,050
61	Sand	4	2,054
62	Clay	15	2,069
63	Lime rock with pyrite	2	2,071
64	Shells	3	2,074
65	Clay	16	2,090
66	Sand with gas	6	2,096
67	Clay	7	2,103
68	Sand	31	2,134
69	Limestone with pyrite	2	2,136
70	Clay	8	2,144
71	Limestone with pyrite	6	2,150
72	Clay	20	2,170
73	Lignite and clay	3	2,173
74	Coarse white sand with pyrite	23	2,196
75	Clay	2	2,198
76	Rock	4	2,202
77	Clay	16	2,218
78	Soft clay	4	2,222
79	Sand with pyrite	6	2,228
80	Blue clay	2	2,230

CLAY.

As compared with the Texas fields, the most remarkable feature of the geology of the Jennings field is the very large proportion of coarse sediments. Clay or gumbo, which is by far the most abundant material drilled through in the Texas fields, here occupies a subordinate position. In the Crowley well No. 3 there are about 421 feet of clay in a total depth of 1,810 feet. The corresponding figures in the Crowley No. 5 are 529 and 1,820; in the Crowley No. 12, 409 and 1,706. In the Superior No. 1 there were 620 feet of clay in a total depth of 1,510 feet. The Jennings Oil Company's well No. 7 had 643 feet of clay in a total depth of 1,870 feet. The data from many other wells are less definite, but there is general agreement that the material is, on the whole, of a coarse texture. The average proportion of clay shown by the logs received is probably less than one-third. On the other hand, a few very reliable logs from points in Acadia Parish, outside the Jennings field, show the proportion of clay to be a little more than one-half. The well at Church Point, 26 miles northeast of Jennings, had 1,022 feet of clay out of 2,006. The record of the Chicago-Jennings No. 1, which is 2 miles northwest of the field, showed, in a total depth of 2,230 feet, clay beds aggregating 1,185 feet.

SAND AND GRAVEL.

The place of importance commonly occupied by clays in the other fields is here held by sand and gravel. The latter is found in a remarkably large proportion. In the reports the gravel is frequently not separated from the sand. Within the first 1,000 feet the mention of a single body of "sand and gravel" or "quicksand and gravel" or "water sand and gravel" from 600 to 800 feet thick is the rule rather than the exception. Even disregarding the proportion of this amount which should be set down as gravel, the aggregate thickness of beds described as gravel alone is frequently several hundred feet. The logs obtained from the wells outside of the productive field show no such thick bodies of sand and gravel.

LIMESTONE.

A further contrast between the formation of this field and of the Texas fields appears in the comparative absence of the thin, hard beds of limestone. A number of wells report no such beds whatever. Over considerable areas they are limited to a few inches in thickness, and even then rarely encountered. In certain well logs there is mention of "soft limestone." Where this description appears the thickness of the bed is usually considerably greater than that of the characteristically thin, hard sheets. This tends further to confirm the supposition that the prompt and early consolidation of the marly sediments, as compared with that of clays and sands, is closely related to their prevailing thinness. The wells outside of the productive field show the familiar prevalence of these limestone beds, which is characteristic of the fields farther west. Thirteen of such thin, hard plates are mentioned in the log of the Chicago-Jennings No. 1. In addition to these the same log records a 40-foot stratum of "soft limestone." The well section at Church Point includes three thin beds of hard limestone and three thicker ones which have not yet become thoroughly consolidated.

Closely related to the beds of limestone are the deposits of shells, which, in the Jennings field, are notably abundant. They may constitute the entire body of a bed, but are more frequently reported in connection with another material, generally clay or gumbo, but in a considerable minority of cases with sand or gravel.

PYRITE.

The occurrence of iron pyrite is relatively frequent. While found at any depth, it is said by well-informed drillers to be far more abundant below a depth of 1,600 or 1,700 feet, or just above the oil. It does not occur in solid masses by itself, but impregnates sediments, sometimes to the extent of thoroughly indurating the beds. It is least often found impregnating sands and gravels. It is more frequently mentioned in connection with shells and clay. Where limestone layers exist, pyrite is still more often named as a constituent of "rock," this word being commonly understood to signify the thin plates of limestone. Generally the rock so impregnated is found to be inclosed between beds of clay.

OCCURRENCE OF THE OIL.

PRINCIPAL ZONE.

The oil at Jennings, as at Saratoga, is found in a sandy zone rather than in a single stratum of sand. The style of formation is that which is customarily spoken of among oil men as "broken sands." This zone may have a thickness of 100 or, in exceptional cases, 200 feet, but is usually much thinner. It lies for the most part between the depths of 1,700 and 1,900 feet. Above this main oil-producing zone are the principal beds of clay or gumbo, most of such beds being found in the lower half or even the lowest third of the well sections. This clay has the position and function of a cap rock. The great depth of the oil in the Jennings field, as compared with that in the other fields, is due to the highly sandy or even gravelly character of the upper sediments. They contain no impervious bed of wide extent. Oil which might otherwise have accumulated in these beds has therefore been allowed to escape to the surface. In some parts of the field a showing of oil was common at a depth of about 1,000 feet. No pay oil was obtained from this zone.

Immediately above the sandy zone which forms the main reservoir for the oil there are generally beds composed largely of shells, and frequently impregnated with pyrite. Such beds, not being entirely impervious, are found to some extent saturated with the oil, and in some cases small producing wells might have been finished in these beds without entering the more porous sands below. This occurrence has given rise to a rather general supposition in this field that the shells and pyrite are in some way connected with the oil. The connection, however, is purely incidental. The overlying bed of shells may be absent at places, while at others it may be separated from the oil sands by a layer of gumbo, the shell bed in the latter case being void of oil.

The depth of the main zone is usually between 1,700 and 1,900 feet. This depth varies in different parts of the field, but all attempts to correlate depths in such a way as to show dips or folds are of no avail. The explanation applied to similar diversities of depth in the Saratoga field (see p. 58) applies with equal fitness to Jennings. The logs of wells of the Crowley Oil and Mineral Company in the northeastern part of the field (see map, Pl. VII, and list of wells, p. 101) make repeated mention of the oil at 1,760 feet. It may be that these occurrences indicate a more or less continuous bed of sand at a nearly uniform depth; but between the wells which found oil at this depth are other wells which found nothing but clay at 1,760 feet, though finding oil considerably higher or lower. Therefore, even if the 1,760-foot level represents one and the same stratigraphic horizon, it must be considered that the bed is not everywhere of sand. Wells on the same tract from 600 to 700 feet farther north find oil 100 or 200 feet higher. Should this, however, be regarded as indicating a southward dip of the sands, the same dip should be expected to appear with some consistency in neighboring tracts. Such consistency is entirely wanting.

Southwest from the Crowley tract toward the center of the field, the 1,760-foot level continues to yield oil in an occasional well, while intervening wells find their supplies of oil at various depths ranging from 1,600 to 1,800 feet. In the extreme western part of the field is a group of wells which may, in general, be said to have found an oil body between 1,800 and 1,900 feet deep, but no consistent dip can be detected within this group. Going south from the center of the field, one finds a vague suggestion of a southward inclination of the oil-bearing zone. That such an inclination would be difficult to determine, even if present, is evident from the fact that the log of the Jennings Oil Company's well No. 7 mentions oil at six distinct horizons between 1,656 and 1,864 feet. Still farther south the Charleston well found some oil at 1,735 feet, which is about the average depth in the central part of the field. Some of the more recently drilled wells in the eastern part of the field, in the Arnaudet tract, have found the oil at depths of about 1,900 feet.

The significance of this utter irregularity in the depths of the various wells lies in the indication that (1) the oil horizon is not a single continuous porous stratum, but a zone having indefinite boundaries and containing many isolated oil-bearing sands; (2) there are no determinable dips, if indeed there are any dips at all, and (3) the varying depths of a group of wells can not be so correlated as to be used as a basis for inferring the probable depths of the oil-bearing sand at any other place.

SHALLOW WELLS.

Some 15 or 20 shallow wells on the southern border of the field found a small body of heavy oil at a depth of about 110 feet. Such wells yielded from one-half barrel to 5 barrels or even more per day. The oil was for a time used for fuel in the drilling of the deeper wells, but later almost the entire product has been used as a lubricant. It will be seen that this occurrence in the Jennings field is very similar to that of the heavy surface oils at Saratoga, Sour Lake, and Nacogdoches.

SALT WATER.

It has been shown by repeated occurrences in the Jennings field that there is an abundant supply of salt water beneath the oil; that this body of salt water may be tapped by wells drilled too deep; and that eventually, with the gradual exhaustion of the oil, wells are invaded by salt water. Certain wells which were drilled too deep, early in 1904, encountered the salt water and may have been partly to blame for allowing this water access to other wells. As late as September, 1904, the large wells in the Arnaudet tract were free from salt water, but later its appearance became general. The Bass & Beckenstein well No. 3 came in as a salt-water well in November, after the water had invaded this part of the field. In such instances it is not improbable that had the well been drilled earlier it would have yielded oil.

In its advance from well to well through the irregularly distributed sands of this field the salt water has shown the same freakishness which was remarked at Sour Lake and other Texas fields. Certain wells, for example the Superior No. 2, have for a long time continued free from salt water after its appearance in large amount in surrounding wells. On the other hand, while the sandy zone which contains the oil can not be regarded as a folded bed, nevertheless, wherever the sands of this zone are sufficiently abundant and close together to afford communication over a considerable area, the effect of this structure in controlling the movements of fluids is the same as that of an inclined stratum of sand. (Compare fig. 12, p. 119.) It may therefore be expected that the behavior of salt water and oil will be controlled largely by their relative specific gravities, as is the case in those fields where the oil is contained in a single continuous bed of porous sand. This is found to be the case, the salt water making a gradual advance from the deeper wells to the shallower in accordance with the well-known laws of its behavior in the Appalachian fields. The spots in which salt water first appeared, and from which it spread to other wells, were near the north and south sides of the field respectively. The group of wells on the extreme west side reached salt water very early.

In addition to the large amount of salt water which presses upward beneath the oil, considerable amounts are found in higher beds. These are, in all cases, separated from the lower oil by impervious clays, and their movements are quite independent of that of the fluids below. In the northern part of the field it was quite common to find a considerable quantity of salt water at depths of from 1,400 to 1,600 feet. In one or more of the great gushers on the east side a strong flow of salt water was also encountered above the oil, and issued between the outer and inner casings, while the well itself produced oil only.

In at least one case (the Guarantee well) a flow of hot salt water was derived from beneath the oil sand. The exact temperature of this water was not taken, but a reliable man reports it as having been so hot that one could barely hold his hand in the water. It is stated by several trustworthy drillers that all the water above the oil has the normal ground temperature and that high temperatures, wherever encountered, come in suddenly below the horizon of the oil. (Compare Batson, p. 56.)

GAS.

It is usually said that the Jennings field does not yield much "dry gas." The significance of this expression is that most of the gas is contained in the beds with the oil instead of in higher strata or pockets, as at Saratoga. Jennings has not been without its blow-outs, a few of them destructive, but these have come from about the same depth as the oil. An examination of the recorded logs will readily show that the formations above the oil lack the extensive clay beds which are necessary as covers in order to retain large accumulations of gas. The gas from the great gushers is of the same poisonous character as that at Spindletop.

LIMITS OF THE FIELD.

The outlines of the Jennings pool are fairly well indicated by the limits of the present development. The area is about 100 acres. A sufficient number of dry wells have been drilled around the edges to show that any great expansion of the field is very doubtful. Considerable drilling has also been done at a distance of 1 or 2 miles from the field. Such wells have generally been drilled somewhat deeper than the producing wells within the field, but thus far they offer no encouragement to further efforts. Ninety-two wells were drilled in this field before the middle of September, 1904. A large majority of these were producers. In the next three months great activity was displayed.

The following is a list of wells completed before October, 1904:

Wells in main portion of the Jennings oil field.

[The numbers on the left correspond to those on the map (Pl. VII).]

Map No.	Owner.	Well No.	Map No.	Owner.	Well No.
1	Crowley Oil and Mineral Co	11	28	Southern Oil Co	7
2	do	5	29	do	8
3	do	3	30	Keoughan & Co	2
4	do	10	31	do	3
5	do	2	32	Mermentau Development Co	1
6	do	8	33	do	2
7	do	7	34	do	3
8	do	1	35	Morse Oil Co	1
9	do	9	36	do	2
10	do	4	37	Morse Oil Co. (Wilkins)	3
11	do	6	38	Morse Oil Co	5
12	do	12	39	do	4
13	Jennings Heywood Oil Syndicate	2	40	Bienville Oil Co	1
14	Crowley Petroleum Co	1	41	do	2
15	Guarantee Oil Co	1	42	Home Oil and Development Co	1
16	Equitable Oil Co	1	43	do	2
17	Swift Oil Co	1	44	Heywood Bro. & Chaddock	1
18	Woods well	1	45	Heywood Bros. Oil Corporation	1
19	Northern Oil Co	1	46	Jennings Oil Co	1
20	do	2	47	Jennings Oil Co	2
21	do	3	48	do	3
22	do	4	49	do	4
23	Southern Oil Co	2	50	do	5
24	do	4	51	Producers Oil Co	1
25	do	3	52	do	2
26	do	6	53	do	3
27	do	5	54	Morse Oil Co	6

Wells in main portion of the Jennings oil field—Continued.

Map No.	Owner.	Well No.	Map No.	Owner.	Well No.
55	Chicago-Jennings Oil Co	2	74	Simon Oil Co	1
56	.....do	3	75	Layne Oil Co	1
57	.....do	4	76	.....do	2
58	Getty et al	1	77	Lake Oil Co	1
59	Savage Bros	1	78	Schultz Oil Co	2
60	Charleston Oil Co	1	79	.....do	1
61	New Orleans Oil Co	1	80	Superior Oil Co	2
62	Rayne Plts. Oil and Development Co	1	81	.....do	3
63	.....do	2	82	.....do	1
64	Texas Oil Co	1	83	Crowley Oil and Mineral Co	13
65	Lyons Oil Corporation	1	84	Jaenke Oil Co	2
66	New Orleans Jennings Mutual	1	85	Crowley Oil and Mineral Co	14
67	Savage, Morrical & Savage	1	86	Tierce	1
68	Western Oil Co	1	87	.....do	2
69	Pelican Oil Co	3	88	Morse	7
70	Eunice-Crowley Oil Co	1	89	Latreille	1
71	H. & R. Oil Co	1	90	Wilkins	......
72	American Oil Co	1	91	Teter	......
73	McFarlain Oil Co	1	92	Virginia	......

WELSH FIELD.

GENERAL DESCRIPTION.

This field is about 3 miles northwest of the village of Welsh, which is 10 miles west of Jennings. In an oblong tract some 1,500 feet northeast and southwest and perhaps half as wide, fifteen wells have been drilled since the summer of 1902, about half of which have produced oil in marketable quantities. None of these wells has been a large producer for any great length of time. The daily production from six or seven wells in August, 1904, was between 300 and 400 barrels.

The site of the Welsh field is a gentle elevation on the otherwise flat Coastal Plain. The elevation is distinctly visible from a distance, and amounts to between 5 and 10 feet, but the boundaries of the mound are not easily defined within narrow limits. The elevated area is approximately the same as that of the developed oil field. It is oblong in shape, having its greatest length in a northeast-southwest direction. Around the edges of the developed field a sufficient number of dry wells have been drilled to make fairly safe the prediction that the productive area will not be greatly extended. At a distance of one-fourth of a mile to the southwest the Texas Company drilled to a depth of 1,200 feet without finding oil. The Decatur well, which is about the same distance south of the field, is 2,012 feet deep, and, though showings of oil were noted at depths of 1,400 and 1,600 feet, the well may be called dry. A short distance northwest of the field the Colorado-Texas Company drilled 2,350 feet, finding only a faint showing of oil at about 1,000 feet. The Brown-Lively well, on the northwest side, is about 1,100 feet deep, and the Boss well, one-fourth of a mile northeast of the field, is about 2,000 feet deep. Both of these are dry, though the latter is said to have found showings of oil at 1,400 and 1,600 feet. Six miles north of the Welsh field the Decatur Company drilled two wells to depths of about 1,200 feet and found no oil. The Spindletop well, which is near the Decatur wells, and is 1,700 feet deep, found only a showing of gas at about 1,000 feet. At Roanoke, 5 miles east of the town of Welsh, are two dry wells said to be 1,100 or 1,200 feet deep. Some 6 or 7 miles southeast of Welsh, the Big Mound Oil and Gas Company drilled a dry hole 1,551 feet deep.

WELL SECTIONS.

The character and vertical distribution of the sediments, both within the productive field and beyond its limits, are well shown in the following sections:

Logs of wells in and near Welsh field.

WELSH OIL AND LAND DEVELOPMENT COMPANY'S WELL NO. 3.

[Received from Mayor L. E. Robinson, Welsh.]

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Clay and gumbo	105	105	11	Pocket of sand with oil	18	1,034
2	Sand	20	125	12	Gumbo	10	1,044
3	Fine sand	42	167	13	Packed sand and oil	10	1,054
4	Coarse water sand	103	270	14	Gumbo	66	1,120
5	Sand with showing of oil	19	289	15	Sand with oil and gas	21	1,141
6	Sand	62	351	16	Gumbo	44	1,185
7	Sand and gravel	23	374	17	Sand with oil and gas	44	1,229
8	Materials not specified except that they contain frequent bowlders and gravel	556	930	18	Blue gumbo	87	1,316
				19	Rock not hard, presumably sand cemented in streaks	15	1,331
9	Gumbo with a fine rock at 996	66	996	20	Rock and sand	64	1,418
10	Gumbo	20	1,016	21	Rock	53	1,471

The total depth of this well as corrected by tape measure should be 1,464 feet. Seven feet should be taken off from the measurements above 930.

BIG MOUND OIL AND GAS COMPANY'S WELL, 7 MILES SOUTHEAST OF WELSH.

[Received from W. N. West, driller.]

1	Red clay	95	95	11	Blue clay	25	785
2	Very fine sand with water	51	146	12	Sand	320	1,105
3	Blue clay	84	230	13	Gumbo	15	1,120
4	Sand and gravel with much water	230	460	14	Sand	45	1,165
5	Blue clay	12	472	15	Blue clay	105	1,270
6	Sand	38	510	16	Sand	38	1,308
7	Blue clay	55	565	17	Blue clay	102	1,410
8	Sand	35	600	18	Sand	65	1,475
9	Blue clay	95	695	19	Shale	55	1,530
10	Sand	65	760	20	Sand; well dry and abandoned at 1,551	21	1,551

The following is a list of wells in and near the field:

Wells at Welsh, La.

[The numbers at the left correspond to those on the map (fig. 9).]

1. Proven Field.
2. Hilltop No. 1.
3. Hilltop No. 2.
4. Hilltop No. 3.
5. Hilltop No. 4.
6. Southern Pacific No. 1.
7. Southern Pacific No. 2.
8. Southern Pacific No. 3.
9. Metropolitan.
10. Welsh Oil and Land Development Company No. 1.
11. Welsh Oil and Land Development Company No. 2.
12. Welsh Oil and Land Development Company No. 3.
13. Welsh Oil and Land Development Company No. 4.
14. Southwestern Oil Company No. 1.
15. McFadden.
16. Texas Company.
17. Decatur Oil and Mineral Company.
18. Colorado-Texas.
19. Brown-Lively.

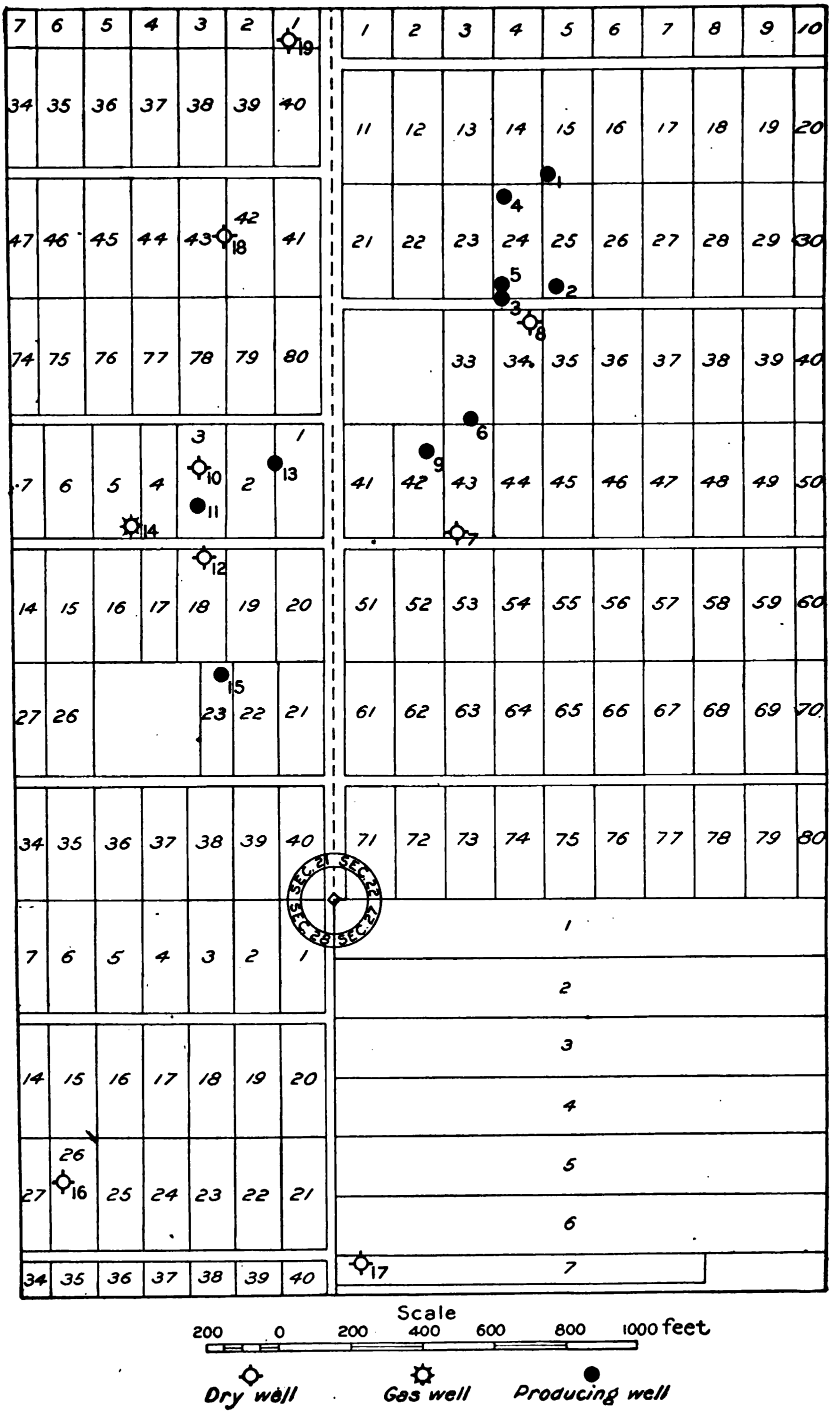
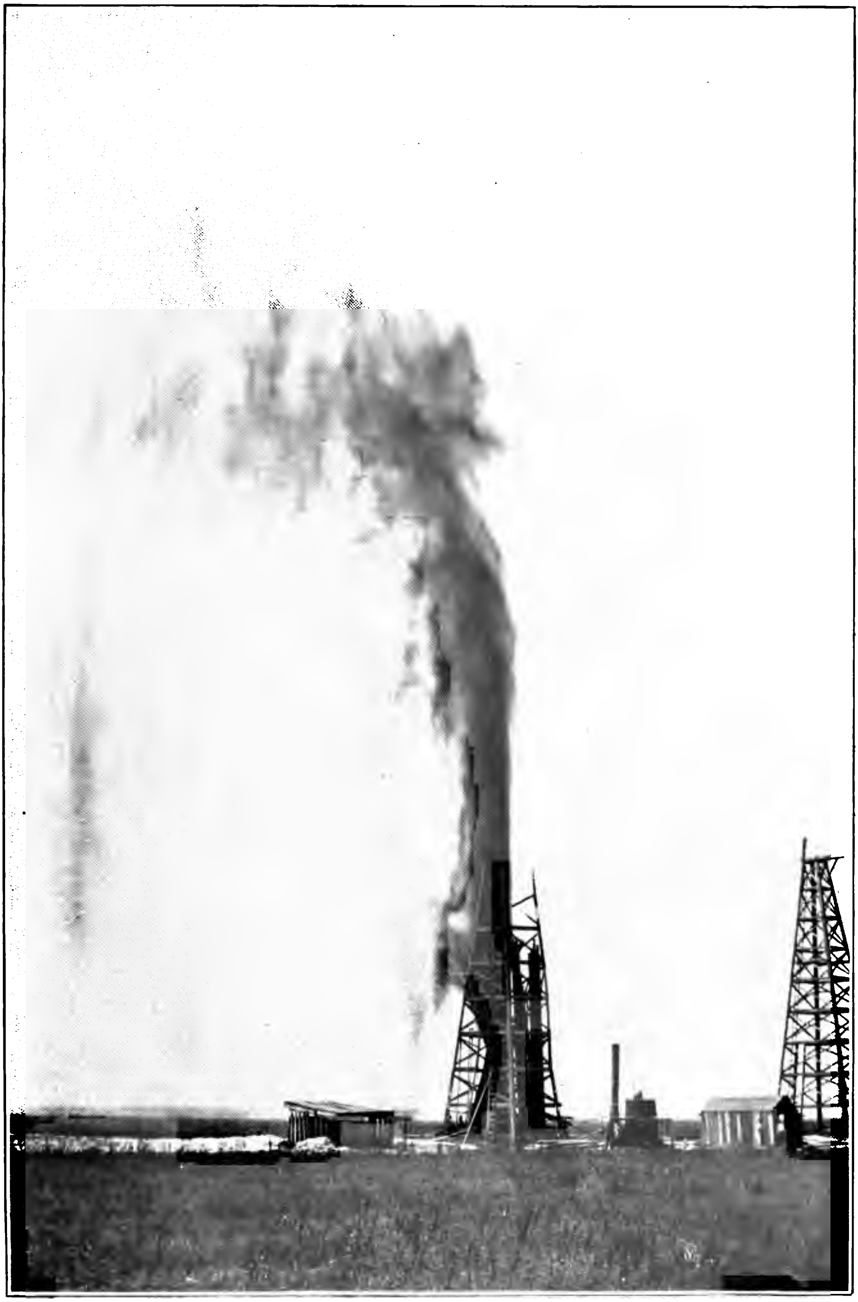


FIG. 9.—Map of the Welsh oil field. The numbers correspond to those in the list given in the text (p. 103).



SAND GUSHER AT WELSH, LA.

All of the oil in the Welsh field is found at depths differing little from 1,000 feet, though faint showings at about 300 feet and again at 700 feet were noted in several instances. The oil is contained in uncompacted sands overlain by a single thick bed of gumbo, or, in other cases, by a succession of beds in which gumbo is prominent. For a depth approximating 100 feet from the surface of the ground the material is commonly reported as clay, but with this exception there is no important clay horizon above that which overlies the oil. The accumulation of oil at a higher level is therefore impossible. At a depth of several hundred feet is a body of sand and gravel, often more than 100 feet thick, from which water is pumped in abundance for the irrigation of rice. No rock is reported except such as is manifestly a partially cemented sand. A thin plate of this nature overlies the oil in a few of the wells, and probably extends over a considerable part of the field. It is frequently spoken of as the "cap rock," but it is probable that the function of holding down the oil and gas is performed mainly by the overlying clays.

GAS.

Gas is found in considerable quantities. Its escape at the surface was the principal indication which led to drilling, though the existence of the mound itself must have been regarded as significant. The greatest quantities of gas are found at the horizon of the oil. The No. 3 well of the Welsh Oil and Land Development Company was ruined by a severe blow-out which came from a depth of 1,100 feet. (See Pl. VIII.) The same company's well No. 4 gushed for nearly one month before it was put to pumping, after which it yielded about 60 barrels daily for a period of at least eighteen months, or until the autumn of 1904. A blow-out in the Metropolitan lasted for about ten hours. On being closed down and cleaned out a year later, a similar blow-out occurred, lasting for about the same period. The McFadden well, after being pumped for one month, began to flow by its own pressure and continued to do this for at least six weeks. A similar occurrence took place in the Southern Pacific No. 1, which flowed from 50 to 75 barrels per day under its own pressure after having been pumped for a number of months.

SALT WATER.

The amount of salt water pumped with the oil at Welsh is considerably greater than that of the oil itself. Some trouble has been experienced in the separation of the Welsh oil from the water which accompanies it. The process requires an inconveniently long time and high temperatures. After the separation the oil may be used for fuel, though in its constitution it differs sufficiently from the other Coastal Plain oils to cause a slight inconvenience in using it in the same burners.

ANSE LA BUTTE FIELD.

DESCRIPTION.

For several years a limited amount of oil has been obtained from the Anse la Butte district. This place is about 8 miles north of Lafayette, La., between Bayou Vermilion and Bayou Teche. The surface here has perhaps 10 or 15 feet of relief, due to stream erosion. In addition to that which is evidently of erosional origin, there is a somewhat symmetrical mound rising a few feet above the general level of the country. (See contour map, fig. 10.) It can not be definitely stated that the elevation at this place is due to the causes which made the salt islands rather than to erosion, but the presence of salt as shown by the well sections lends a strong probability to that supposition. Moreover, the form of the elevation has sufficient regularity to suggest an origin similar to that of the salt islands and the oil mounds of the Coastal Plain. Besides the more or less symmetrical mound, there are other limited elevations whose appearance is intermediate between that of the mound and that of purely erosional features. The center of the district in question is occupied by a swamp about 1,500 feet long and 1,000 feet wide.

Within an area about 1 mile east and west by a mile and a half north and south 15 wells were drilled before the close of the summer of 1904. Most of these found showings of oil, and at least four have produced small amounts of oil for the market. None had an initial capacity much in excess of 100 barrels per day. In February, 1905, but two wells, the Heywood Nos. 1 and 2, continued to produce, showing little diminution of capacity after two years' production. They were pumped with air, and yielded enough oil to supply the fuel used in drilling another well and to satisfy a small local demand. Several more producers were drilled during 1905, one of which, the Lake No. 2, is 1,808 feet deep. The capacities of the newer wells are similar to those of the older.

SURFACE INDICATIONS.

In and around the swamp gas is seen to escape, sometimes in large quantities. Within the swamp itself this gas has given rise to a number of small mud volcanoes. On the northern edge is a so-called gas spring; it should rather be spoken of as a considerable area of soft ground from which much gas escapes. Through 2-inch pipes driven into this ground by hand gas may escape at such a rate as to support a flame several feet in height. On the east side of the marsh an asphaltic substance is found, at places, about 8 inches beneath the surface of the ground. This substance so strongly impregnates the subsoil as to give to it something of the consistency of rubber, making it difficult to cut with a spade. In addition to these phenomena, which have for a long time suggested the possible presence of oil, there are springs of sulphureted water, especially on the southeast side of the field. The presence of water thus mineralized has been regarded with some interest on account of its association (fortuitous or otherwise) with some of the larger oil fields, notably Sour Lake.

WELL SECTIONS.

The following logs are selected as representative well records of this field. They show the types of sediments and the occurrence of the salt bodies.

Logs of wells in Anse la Butte field.

HEYWOOD NO. 1.

[B. H. Harper, driller.]

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Sand and gravel, mostly gravel	268	268	4	Sandy clay or cemented sand	60	1,060
2	Salt	272	540	5	Sand	290	1,350
3	Clay	460	1,000	6	Salt, not passed through	200	1,550

Some oil at 1,100 feet or thereabouts; now producing about 20 barrels of aromatic oil per day; produced about 40 barrels per day at first.

HEYWOOD NO. 2.

[W. Scott Heywood, driller.]

1	Water sand and gravel	300	300	4	Blue clay	85	570
2	Clay	100	400	5	Small gravel with gas and oil capable of producing 10 barrels per day	23	593
3	Clay and coarse oil sand capable of producing 8 barrels per day	85	485	6	Clay	15	608

The log of this well was received from the driller, Mr. Heywood, and is guaranteed to be correct. The well contains two screens, in the 485-foot sand and 593-foot sand, respectively. Its daily production is from 15 to 18 barrels.

Logs of well in Anse la Butte field—Continued.

MORESI NO. 1.

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Clay	40	40
2	Sand, with showing of oil	16	56
3	Sand and gravel	130	186
4	Soft rock	21	207
5	Sand and gravel	114	321
6	Hardpan and blue clay	81	402
7	Blue shale	38	440
8	Oil rock	110	550
9	Limestone	50	600
10	Rock, perhaps sandstone (?)	291	891
11	Blue clay with oil	47	938
12	Oil sand	23	961
13	Sand and rock mixed	69	1,030
14	Rock (sandstone?)	15	1,045
15	Oil sand	105	1,150
	Quit in shells below oil sand.		

From 600 to 938 was the best showing of oil. The well produced salt water. When pumped, might have produced 10 barrels of oil per day from about 700 feet deep.

ANSE LA BUTTE OIL COMPANY'S WELL NO. 2.

[Published by Dr. C. F. Z. Caracristi in a report to the company.]

1	Yellow clay	37	37
2	Fine sand	3	40
3	Sand and gravel	10	50
4	Coarse sand	50	100
5	Fine gravel	50	150
6	Sand and gravel	50	200
7	Coarse sand	25	225
8	Rock	1	226
9	Oil-bearing sand	2	228
10	Rock	7	235
11	Gravel	2	237
12	Rock	3	240
13	Sand	2	242
14	Gravel	18	260
15	Rock and gravel	5	265
16	Oil-bearing sand	3	268
17	Gravel	17	285
18	Sandstone	5	290
19	Hardpan	30	320
20	Sand and gravel	30	350
21	Gravel	4	354
22	Sand	10	364
23	Blue shale	26	390
24	Salt	180	570
25	Rock (flint)	6	576
26	Gravel	2	578
27	Salt	212	790
28	Sand and gravel	11	801
29	Cap rock	½	801½
	Gas and some petroleum.		

DRILLER'S NOTE.—Gas pressure at base of well 700 pounds to the square inch.

SEDIMENTS.

Anse la Butte is situated on the outcrop of the Port Hudson formation, as mapped by the Louisiana Geological Survey. The beds passed in drilling are generally uncompacted sands, gravels, and clays. The proportion of sand and gravel is large as compared with that found in the Coastal Plain oil fields of Texas. Thick beds of clay are not common above a depth of 700 or 800 feet. Lower than that, some massive clay formations are found, especially in the outlying wells at some distance from the center of the field. The reports of thin beds or plates of hard rock, so common in the Texas fields, are almost wholly wanting at Anse la Butte. A few notations of such occurrences are taken from the records of wells northwest of the swamp. There is frequent mention of "rock," but the thicknesses of beds so named are generally far greater than those noted in the Texas fields. The rock is also frequently soft and is sometimes specifically said to be a sandstone or soft sandstone. From all the well records obtainable, as well as from a few specimens seen, it may be fairly inferred that the type of rock which has received frequent mention in the records of the Anse la Butte wells is a sand more or less cemented by carbonate of lime. The harder parts are doubtless often concretions.

Data were obtained from nearly all of the wells named in the following list:

Wells at Anse la Butte, La., September, 1904.

[The numbers at the left correspond to those on the map (fig. 10).]

1. Heywood No. 1.
2. Heywood No. 2.
3. Heywood No. 3.
4. Heywood No. 4.
5. Heywood No. 5.
6. Lucas.
7. Anse la Butte Oil Company No. 2.
8. Moresi No. 1.
9. Moresi No. 2.
10. Moresi No. 3.
11. Moresi No. 4.
12. New Iberia Oil and Mineral Company.
13. Southern Pacific No. 1.
14. Pioneer.
15. New York and Acadia.

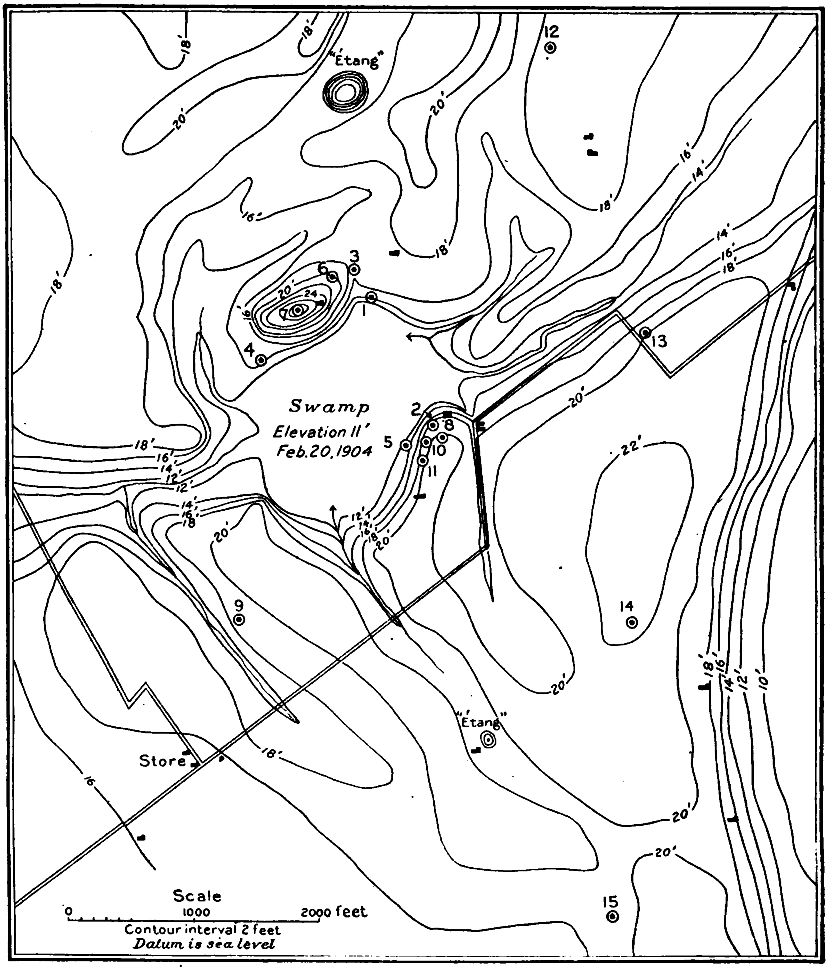


FIG. 10.—Map of Anse la Butte, La. Surveyed in February, 1904, by G. D. Harris. ⊙ Oil wells. The numbers attached correspond to those given in the list in the text. Nos. 1, 2, 8, and 11 have produced oil.

OCCURRENCE OF THE OIL.

The oil occurs in sandy beds and generally at no great depth. In the Myers well (Heywood No. 5) these beds are spoken of as "softer places" within a thick body of rock encountered at a depth of 308 feet. From an examination of the materials, it appears that these so-called "softer places" are uncemented sands included between well-cemented beds of similar material. The "rock" from which oil is derived in the Moresi No. 4 is probably of the same character, although in this instance the oil was obtained at or near the top of the rock. In all the other cases it seems clear that the oil comes from porous beds of sand, gravel, or sandy clay. The one occurrence which is peculiar to this small field, and of exceptional interest, is the finding of a so-called "aromatic oil" at a depth of 1,000 to 1,060 feet in the Heywood No. 1, this being beneath the 272 feet of rock salt which was passed in the upper half of the well section.

GEOLOGIC STRUCTURE.

Various attempts have been made to correlate the data of the different wells in such a way as to show dips of certain beds which have been assumed to be continuous from well to well. From the available data of nearly all the wells drilled previous to September, 1904, it is quite safe to say that no correlation is possible; that the formations, so far as they are continuous from well to well, can not be recognized or identified; and, therefore, that it is not possible from the present data to infer dips or folds in the structure. A 6-inch core of rock taken from one of the wells on the east side of the swamp shows markings which are inclined at a high angle, presumably toward the southeast. These lines have been supposed by some to represent bedding and therefore to indicate a pronounced uplift near the center of the field. From an examination of the core referred to, this inference is believed to be not wholly established. The markings resemble joints or fractures which have been recemented quite as much as bedding planes. There is no inherent improbability in the assumption of deformation which would tilt the bedding planes to the southeast; that is, away from the salt body. Such deformations have been noted elsewhere in similar relations, but only to a very slight degree in the gently domed structures of the oil-bearing mounds. It is not yet demonstrated that there is an uplift at Anse la Butte of greater intensity than those noted in the larger and better-known oil fields of the Coastal Plain. (Compare pp. 35, 44, 54.)

SALT.

Salt was reached or passed through in three or four wells, but its depth and thicknesses are so diverse at different places that it is impossible at present to assign even an approximately exact form to the body or bodies of salt. The original Anse la Butte (Simpson) well passed through 189 feet of salt between the depths of 381 and 570 feet. Beneath this salt were 8 feet of "rock" and gravel; the drill then entered salt again, which it passed through at a depth of 790 feet, thus showing an entire thickness of 401 feet. Though showings of oil and gas were noticed, this well never produced. The record of the Heywood No. 1, on the northern margin of the swamp, shows 272 feet of salt between the depths of 268 and 540 feet. This well entered salt again at a depth of 1,350 feet and drilled 200 feet farther without passing through the salt body. Between 1,000 and 1,060 feet the well produced oil at the rate of about 20 barrels per day. The Heywood No. 4, west of the swamp, entered salt at a depth of 220 feet and stopped in the same formation at a depth of 1,803 feet. Reports differ as to the finding of salt in certain other wells and, to some extent, in the thickness of the salt formations already named.

If these salt bodies are connected in one continuous mass, it may be inferred that the Heywood No. 4 pierced the central body, and that the salt passed through in the Simpson well and the Heywood No. 1 represents offshoots from this body. It may well be supposed that such offshoots would be controlled to some extent, in form and position, by bedding planes. The diversity of depths and thicknesses of salt bodies, however, throws grave doubt on the theory that there are sedimentary beds of salt, and suggests that the bodies here encountered are of secondary origin and that they follow lines determined by the movements of ground water, which, in turn, were influenced by the character and distribution of the sediments. Inasmuch as the oil is chiefly on the east side of the swamp and the salt on the west side, it would seem probable that, so far as there is a central oil body, it branches out to the sides in porous sands in forms similar to those of the body of salt, and that the Heywood well No. 1 is located at a place where the branches of the salt body and the branches of the oil body are, in a manner, dovetailed. There is a similar occurence at Belle Isle, where a well was drilled near the edge of the salt body. After passing through five beds of salt, aggregating about 250 feet and alternating with sediments, a sand was reached at 1,475 feet which contained a very small quantity of light straw-colored oil.

Salt water is found in all parts of the Anse la Butte field. As in the other fields, it may be found either above or below the oil, but in the former case the two are always separated by an impervious bed. Gas is found in moderate quantities, generally above the oil.

MINOR LOUISIANA DISTRICTS.

VINTON.

About 4 or 5 miles southwest of the village of Vinton, La., is a mound covering about 800 acres. It rises 35 feet above the surrounding country and 50 feet above the level of the sea. It is approximately circular in form, but contains an irregular depression or trough which partly isolates a portion of the mound on the east side. This is the portion which has been of interest in the matter of oil. Gas bubbles have long been observed rising to the surface in the swampy depression or in other places when covered by the water of recent rains. Seepages of oil have likewise been observed, forming films on standing water. It is also said that the water of shallow wells has suggested petroleum by its taste. Certain springs of water, about a mile east of the mound, have been noticed to possess a sour taste similar to that of the waters at Sour Lake.

There are at present four shallow wells which derive a heavy oil from a depth of about 26 feet. These wells are pumped by hand and yield on an average about 15 gallons of oil per day. The oil is used for lubricating purposes by the large lumber concerns at or near Vinton. More of these wells will doubtless be drilled. It is estimated by the proprietor that one man could attend to 12 or 15 shallow wells, pumping by hand about 15 gallons daily from each well.

Since 1902 there have been at least six attempts to drill deep wells. Three of these have been successful in getting down to the desired depths. In the others is was found that the rotary drill was unable to penetrate a thick stratum of gravel which was found about 400 feet deep. The stones of this gravel are at some places so large that the return current of water is unable to bring them to the surface. The three wells which succeeded in passing this stratum of gravel attained depths of 1,100 to 1,200 feet. Oil was not found in sufficient quantities to pump, but the sections of these wells made known some interesting facts regarding the formations.

There were in all cases at least 20 feet of surface clay. Some wells report no clay or gumbo whatever below this. Others found clay in subordinate quantities to a depth of nearly 400 feet. Beyond this depth is the bed of coarse gravel mentioned above, which is in some cases 100 feet thick. This gravel is water bearing, but whether the powerful artesian flow which now issues from the Vinton Oil and Sulphur Company's well No. 2 comes from this gravel or from a lower bed is not definitely determined. In any case the source of the flow seems to be above a depth of 600 feet. The occurrence of artesian water under great pressure at this depth doubtless indicates the presence of a rather widespread bed of clay immediately above the horizon of the water. The well sections (none of which were accurately recorded) indicate that the principal material from this depth to 950 feet is sand or poorly cemented sandstone. Below 950 feet a formation was encountered which is reported as gypsum, though in the absence of satisfactory samples it must remain a question whether the next 150 feet is really gypsum or partially consolidated marl. It is said to have contained occasional showings of oil.

There is frequent mention of sulphur, and specimens of pure sulphur nearly one-half inch in diameter were seen. Its mode of occurrence is in doubt. It is quite probable that, despite the records of "pure solid sulphur," some of it occurs in a disseminated form in beds of sand. The existence, however, of small pieces of solid crystalline sulphur suggests the inference that certain beds of limestone were passed which contain sulphur in small caverns, and that the occurrence is therefore not very different from that at Spindletop or at Sulphur Mine, Louisiana, which is 15 miles northeast of the Vinton mound. The fact that certain specimens of limestone, coming from an unknown depth, are crystalline and resemble the oil rock of the Texas fields, gives probability to this supposition. The depth of one sulphur bed is said to have been 538 feet. It is reported again at about 1,000 feet, associated with the so-called gypsum.

From the samples examined it is quite certain that some gypsum was passed through. No cores were taken out and it is therefore impossible to determine whether the gypsum constitutes a solid body or whether it exists merely in a disseminated form.

The Vinton mound possesses a certain interest because it contains the materials which are characteristically associated with the oil-bearing mounds. In so far as well records were kept it appears also that the general order of succession of the materials here is the same as at Spindletop. Aside from the purely sedimentary beds sulphur is the first characteristic material encountered by the drill. The gypsum appears at a greater depth, as it does at Spindletop. Although rock salt is not reported at Vinton, certain samples from the wells are very salty. Some of the sediments are impregnated with pyrite. Considerable gas was liberated. That which now bubbles up with the artesian water from the Vinton Oil and Sulphur Company's well No. 2 is in large part hydrogen sulphide.

HACKBERRY ISLAND.

This so-called island is a mound surrounded by coastal marsh. It reaches a maximum height of 35 feet, being steepest on the northwest side toward Black Lake and sloping gently to Calcasieu Lake on the east. From the surface of this mound much gas escapes, and some of the spring and well waters are strongly sulphureted. These are the features which have been supposed to indicate the presence of oil.

Three wells have been drilled here by the Louisiana-Texas Oil Company. Nos. 1 and 3, on the east side of the island attained a depth of 1,460 feet. The records of these wells show uncompacted clays, sands, and gravels to 908 feet. Beyond that depth thin plates of hard rock were noted at frequent intervals. These are variously described, sometimes as limestone and sometimes as sandstone with a calcareous cement. A 7-foot bed of lignite was found at 1,421 feet in well No. 1. The sands near the bottom of the well contain a considerable amount of pyrite. There was a showing of oil at 1,460 feet.

Well No. 2 (see p. 112) on the northwest side of the island, near Black Lake, shows a section which is similar to that of the other two wells to the depth at which those wells stopped. At 1,565 feet the drill entered a stratum of limestone 45 feet thick. From detailed descriptions received from the driller, Mr. H. H. Jones, whose observations are trustworthy, it appears that samples obtained from this limestone are entirely crystalline and porous, and that therefore it is very similar to the characteristic oil-bearing limestone of the Texas fields. It did not, however, produce oil in this case. Below this limestone were 10 feet of black sand. The water used in drilling was lost in this sand and several hundred loads of clay were pumped into the well in the form of slush before the pores of the sand were, in a measure, stopped and the return current of water recovered. A showing of oil was noted near the bottom of the well and may have come from this sand, though this is not certain. Salt water was likewise encountered and may have come from the same source. Below this sand, between the depths of 1,620 and 1,830 feet, is a gray-white material described as having little grit and not affected by acid. Samples of this material were not seen, but it is called gypsum by two or three observers who are believed to be competent judges. The position of this formation, with reference to the porous limestone, is the same as that of the gypsum at Spindletop. To judge from the analogy of other districts, it may be regarded as useless to drill this well deeper, though it can not be positively stated that the oil might not be found at some other spot on the island.

Louisiana and Texas Oil Company's well No. 2, Hackberry Island, Louisiana.

[H. H. Jones, driller.]

	Formation.	Thickness.	Total depth.
		Feet.	*Feet.*
1	Sand, gravel, and gumbo with many shells	832	832
2	Rock, probably sand well cemented	3	835
3	Mostly gumbo, with streaks of clay and sand	657	1,492
4	Hard rock, the same as above. Acid affected but did not consume it	2	1,494
5	Alternating gumbo and sand, with streaks of something like brownish asphalt; might have been lignite	71	1,565
6	Limestone purely crystalline, porous or cavernous	45	1,610
7	Very fine sand, pure black	10	1,620
8	A gray-white material, with a little grit not affected by acid. This was called gypsum	210	1,830

BAYOU BOUILLON.

Where Bayou Bouillon, or Larumpe River, enters the Atchafalaya, some 30 miles northeast of New Iberia, La., there is a considerable area which is characterized by the abundance of gas which issues from the ground. In fact, the bayou is said to take its name from the bubbling up of gas through its waters. There are occasional occurrences of oily or asphaltic matter in the soil. These phenomena, more especially the former, led to drilling in the hope of finding an oil body. Up to the present time at least six wells have been started, three of which attained considerable depths.

Samples of the gas were analyzed by Professor Metz, of Tulane University, who finds 93.72 per cent to be hydrocarbons. It is not stated what proportion of the whole is marsh gas. Professor Metz finds no hydrogen sulphide, which is so common a constituent of the gas of the Texas oil fields. The gas is very similar to that which is found elsewhere in the delta and coastal region of Louisiana.

The oil, which has been found in small quantities at shallow depths, has also been analyzed by Doctors Metz and Eustis. It is of a dark-brownish or black color, very viscid and having a specific gravity of 0.859. The fractional distillation of this oil resulted as follows:

Fractional distillation of oil from Bayou Bouillon, Louisiana.

Temperature.	Product.	Percentage by volume.
Below 150° C	Chiefly water	4.3
Below 300° C	Illuminating oil	28.4
Above 300° C	Lubricating oil	42.0
	Asphalt and coke	15.5
	Loss	9.8
		100.0

The few logs obtained, though taken from wells not far apart, are very different. This diversity may be supposed to indicate that no one bed has any considerable lateral extent. If this be true, it may be inferred that no large oil body could be retained below the horizon protected by the surface clays and above the depth at which the wells stopped. From the meager data at hand it is not possible to state positively that the continuous clay beds which are necessary as cap rocks are wanting, but the amount of clay reported in the Maxwell & Sherwood well is very small (see p. 113). There is frequent mention of clay mixed with sand, but the beds distinguished as pure clay are never more than 5 feet in thickness. Under such beds a showing of oil was generally noted. A 300-foot limestone is reported in this well between the depths of 850 and 1,150 feet. The Shelbourne well, whose log is given below, shows much more clay or gumbo. A stratum 173 feet thick was encountered at a depth of 390 feet, and most of the material between that depth and 810 feet is clay, or contains a considerable admixture of clay. In each of these wells a number of thin plates of rock were passed. In another well, not specifically named, a sandy bed between 1,200 and 1,280 feet yielded salt water said to be hot enough to burn the hand.

Logs of wells on Bayou Bouillon, Louisiana.

SHELBOURNE WELL.

[Received from Mr. Robert Martin.]

	Formation.	Thickness.	Total depth.		Formation.	Thickness.	Total depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Clay	62	62	13	Hard gumbo	21	622
2	Sand	176	238	14	Soft gumbo, with some gas, showing a little oil	24	646
3	Hard gravel and sand	10	248	15	Gumbo	24	670
4	Fine sand and gravel	50	298	16	Very soft gumbo	55	725
5	Rock	4	302	17	Gumbo, with fine gravel and shells	27	752
6	Sand	28	330	18	Rock	1	753
7	Heavy gravel	2	332	19	Gumbo, with gasa nd some showing of oil	17	770
8	Rock	2	334	20	Rock or hard gravel	4	774
9	Sand	56	390	21	Sand and gravel, showing oil	36	810
10	Gumbo	173	563				
11	Gumbo, gravel, and pockets of gas, showing some oil	43	606				
12	Gumbo	5	611				

MAXWELL & SHERWOOD WELL.

1	Sand	5	5	23	Sand and gravel	6	314
2	Red clay	15	100	24	Sand	10	324
3	Gumbo and sand	80	100	25	Sand showing oil	6	330
4	Gray sand and gas	5	105	26	Small gravel	8	338
5	Sand and clay	58	163	27	Gravel and gumbo	14	352
6	Gravel and shell	3	166	28	Small gravel	30	382
7	Gray sand	4	170	29	Gumbo, gravel, and sand	81	463
8	Fine sand and gumbo	38	208	30	Gumbo	3	466
9	Rock	2	210	31	Coarse gravel	134	600
10	Sand	4	214	32	Gumbo and fine gravel	20	620
11	Gravel	14	228	33	Sand	30	650
12	Gumbo	3	233	34	Gravel and gumbo	30	680
13	Coarse white sand showing oil	8	242	35	Coarse gravel	10	690
14	Fine sand showing oil	4	246	36	Sand	30	730
15	Gumbo	1	247	37	Gumbo and gravel	20	740
16	Sand showing oil	9	256	38	Sand and gravel	70	810
17	Gumbo	2	258	39	Coarse gravel	20	830
18	Gumbo and sand mixed	18	276	40	Rock (lime)	20	850
19	Gravel	20	286	41	Coarse sand	300	1,150
20	Sand	10	296	42	Sand	140	1,290
21	Sand showing oil	8	304	43	Blue sand (rock)	265	1,555
22	Sand and gumbo	4	308				

Water was salty below 1,000 feet. From 1,150 to 1,200 feet water overflowed pipe.

ORIGIN AND ACCUMULATION OF OIL BODIES.[a]

ORIGIN OF PETROLEUM.

CLASSIFICATION OF THEORIES.

The origin of petroleum is one of the most obscure problems by which geologists are confronted. Numerous widely different theories have been advanced and advocated by geologists and chemists during the last fifty years, but as yet there is none which can be regarded as generally accepted and of universal applicability. In the present connection any full discussion of these theories is manifestly out of place, and only a bare outline of the more important ones will be given. It should be stated, however, that numerous facts have come to light in the development of the Coastal Plain field which have a very direct bearing upon theories of the origin of the oil. These have in part been given in the preceding pages, but will be stated more explicitly in this and the following sections.

The theories may be divided into three main groups: (1) Those which attempt to explain the origin of oil by inorganic agencies; (2) those which ascribe it to an organic origin; and (3) those which involve both inorganic and organic agencies.

THEORIES OF INORGANIC ORIGIN.

In 1866 Berthelot suggested that water containing carbonic acid or an earthy carbonate coming in contact with metallic sodium or potassium at a high temperature might produce both liquid and gaseous hydrocarbons such as are found in various oil fields. In 1877 Mendeljeff published his theory, which remains the most plausible of all the inorganic theories thus far proposed. Stated briefly, it is that water percolating downward through fissures in the earth's crust comes in contact, under conditions of high temperature and great pressure, with metallic carbides; that a chemical reaction takes place, with the formation of metallic oxides and saturated hydrocarbons, and that the latter ascend and impregnate the porous beds of sedimentary rocks in which they are now found.

Various modifications of the theories of Berthelot and Mendeljeff have been suggested by other chemists, but these contain the essentials of all the purely inorganic theories which merit consideration.

The fact is unquestioned that hydrocarbons similar to or identical with some of the constituents of natural petroleum may be produced in the laboratory by the action of inorganic substances, but no geologic or other evidence that these reactions actually take place in the earth's crust has been discovered. The conclusion must therefore be that while the inorganic theory is attractive it is not proved.

THEORIES OF ORGANIC ORIGIN.

These theories may be again divided into two groups: (*a*) That petroleum is indigenous to the rocks in which it is found, and (*b*) that it is the product of natural distillation.

The first of these theories was advocated by Sterry Hunt, who asserted that all petroleum was formed in limestone by the decomposition of the animal remains which it originally contained. It was also advocated by Lesley and Whitney.

The theory was further amplified by Orton, who extended it to the petroleum found in the shale and sandstone in the Appalachian field as well as that found in limestone. According to Orton,[b] petroleum results from the primary decomposition of organic matter, and was formed when the rocks containing it were themselves formed.

A modification of this theory has recently been advanced—namely, that the oil, instead of being the product of decomposition of organic matter, is secreted by living organisms of a low order, such as diatoms, and therefore exists as such as an original constituent of the rock in which it is found. The presence of oil associated with diatoms in the mud at Sabine Pass is regarded by Doctor Phillips as furnishing some degree of support to this theory. [See p. 74.]

The majority of geologists have held to the second theory—namely, that petroleum is derived from the organic matter disseminated through great masses of carbonaceous shales by the process of slow natural distillation at relatively low temperatures, and that it has subsequently migrated through the strata to the reservoirs in which it is found. In proof it is pointed out that these carbonaceous shales yield by artificial distillation a large quantity of hydrocarbons, both gaseous and liquid, which are indistinguishable from those found in nature; but the possibility of natural distillation at a temperature sufficiently low to leave the inclosing rocks entirely unchanged has not been proved, nor have the residues of carbon which would result from such distillation been found in the rocks.

Again, there is much diversity of opinion among those who hold to the organic origin of petroleum as to whether its source is in animal or vegetable remains. Peckham believes that petroleum may be derived from both animal and vegetable matter, but that the source of the organic matter determines the character of the oil, that with a paraffin base (e. g., Pennsylvania) being derived from plant remains, and that with an asphalt base (e. g., California) being derived from animal remains.

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[a] Reprinted with slight revision from Bull. U. S. Geol. Survey No. 212.
[b] Ann. Rept. Geol. Survey Ohio, 1890, p. 85.

THEORIES OF COMBINED ORGANIC AND INORGANIC ORIGIN.

Among the theories which fall in the third group may be mentioned that proposed by O. C. D. Ross [a] in 1891. It is that petroleum is produced by the action of volcanic or solfataric gases containing sulphurous acid and hydrogen sulphide upon limestone, with the formation of gypsum and free sulphur. The reactions given undoubtedly take place in the laboratory, and they may also take place in certain localities in nature. On the other hand, Hopkins [b] proposed a theory, which has been elaborated and modified somewhat by other chemists, according to which the gypsum is the original material and the limestone is secondary. The essential features of this theory are that gypsum, calcium sulphate, in the presence of decomposing organic matter which gives off carbonic acid, is reduced, with the formation of limestone, calcium carbonate, free sulphur, and hydrocarbons. This reaction has not been exactly reproduced in the laboratory, but neither can the conditions which must prevail at great depths in the earth be exactly reproduced.

It will be observed that the theories of this group are intermediate between those of the first two classes. The original materials are in part organic (limestone and vegetable or animal matter) and in part inorganic (volcanic gases and gypsum).

CONCLUSION.

This great diversity of views regarding the origin of petroleum is equaled by the diversity in character of the petroleum itself and in the geologic conditions under which it is found. In fact, it is probable that the final theory will include most of those outlined above, and will recognize the fact that this substance which is so widely distributed in nature may be the product of widely different processes acting upon a great diversity of materials. Thus the hydrocarbons which have been observed in certain volcanic rocks and in gases given off from volcanic vents may be entirely inorganic, resulting from the reaction between water and heated metallic carbides. The oil of the Appalachian field may be derived from the slow distillation of plant remains disseminated through the underlying shales, and that of the Trenton limestone of the Lima field from animal remains originally contained in the rocks in which it is now found. [Finally, the oil of the Gulf Coastal Plain may be derived, in part at least, from the action of decomposing organic matter, both animal and vegetable, but chiefly the latter, upon gypsum or limestone, either as sediments or borne in solution in the sea water which originally permeated the sediments.]

ACCUMULATION OF THE OIL.

CONDITIONS FOR ACCUMULATION.

Hydrocarbons of the petroleum type are among the most widely distributed substances in nature. They are found associated with almost all classes of rocks, both crystalline and sedimentary, from the oldest to the youngest. While these hydrocarbons are very widely distributed they are, however, usually in small quantities, and accumulations sufficiently large to be of commercial importance are restricted by certain well-defined conditions to a relatively small portion of the earth's surface. In many regions it is comparatively easy for the geologist, by an examination of surface conditions, to state definitely and with certainty that no oil in commercial quantities will be found. In other large regions he can state that oil may be found, and can point out in some cases the most favorable localities, but he can not predict the actual occurrence of an oil pool in advance of drilling.

The essential conditions for the accumulation of oil are (1) a sufficient supply of oil derived from any of the sources above described, (2) a porous reservoir rock in which it may be stored, and (3) an impervious cap rock which will prevent its escape. Conditions which favor its accumulation but are not always essential are (4) gentle undulations of the strata forming anticlinal arches or domes, (5) the complete saturation of the rocks with water and its slow circulation under hydrostatic head or convection due to differences of temperature.

THE OIL SUPPLY.

This is of course the first and most essential condition, for without it no accumulation could take place however favorable other conditions might be. Of all the conditions enumerated above this is probably the one which prevails over the largest areas. Wherever there are heavy deposits of sedimentary rocks some of the beds generally contain organic material, either animal or vegetable, from which an abundant supply of hydrocarbons might be derived, and doubtless in a large proportion of cases at sometime in the history of such beds conditions have been favorable for its conversion into petroleum. This is notably true of the many thousand feet of strata constituting the Cretaceous and Tertiary formations on the Gulf Coastal Plain.

THE RESERVOIR ROCK.

All granular rocks which enter into the composition of the earth's crust are to some extent permeable to liquids. This porosity, the vacant space between the rock particles, varies from less than one-half of 1 per cent in rocks like granite to 8 or 10 per cent in ordinary compact, fine-grained sandstones, and 25 per cent or even more in coarse gravel or cavernous limestone and dolomite. The porosity of a rock depends upon the shape of the grains, their uniformity in size, and the amount of cementing material. It is wholly independent of the size of the grains. Hence a fine-grained sand may have as great capacity for holding oil as a coarse gravel. The term "oil pool" is in common use in most oil fields and is a convenient one, but is liable to lead to misapprehension. An oil pool is simply a restricted portion of any porous bed which is saturated with oil. It is limited both vertically and horizontally by some impervious barrier which prevents the escape of the oil. It does not generally contain any large fissures or caverns, the oil being contained in the minute spaces between the constituent grains of the bed. In exceptional cases, such as the Spindletop pool, where the reservoir rock is a limestone or dolomite, there are cavities of appreciable size, probably to be measured in inches and possibly in feet, in which the oil is stored, as well as in the minute spaces between the constituent grains of the rock.

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[a] Chemical News, vol. 64, 1891.

[b] Report on the Geology of Louisiana, 1869.

[There is no difference between an "oil sand" and a "water sand" except that the pores of the former contain oil, while those of the latter are filled with water. The popular belief, therefore, that an expert can tell by examining a sample of sand whether the formation "ought to contain oil," has no foundation.]

The character of the reservoir rock does not determine the character of the oil, but does determine its behavior when the pool is tapped by the drill. When the rock is a firm, fine-grained sandstone, it yields its oil slowly, even when under great pressure, and the yield continues for a long time, steadily decreasing, however, as the supply is drawn from increasing distances. A cavernous dolomite, on the other hand, offers little resistance to the passage of the oil toward the well, and the flow from such a rock is consequently rapid and short-lived. When the oil is held in an unconsolidated sand the latter flows toward the exit along with the oil and quickly chokes the well unless held back by some straining device.

THE IMPERVIOUS COVER.

Since petroleum has a lower specific gravity than water, it always tends to rise when the two liquids are associated in the rocks, and if not stopped by some impervious barrier would continue until it reached the surface and then be dissipated. An essential condition of any large accumulation is therefore an impervious stratum which shall check this upward course of the oil and restrain it in a porous reservoir rock below. Such impervious strata usually consist of fine clay, clay shale, or muddy limestone. If the bed is perfectly continuous, a few feet in thickness of clay or clay shale is sufficient to prevent any leakage from the underlying porous beds even under great pressure. In the Spindletop pool the cover is formed by a considerable thickness of alternating clay beds and limestones. * * * [The so-called "cap rock" is a dense crust of the porous, oil-bearing limestone. The term is often loosely used with reference to the entire body of the limestone.]

ANTICLINAL STRUCTURE.

When oil, whatever its origin, occurs in a porous bed along with water, it tends to rise toward the surface and continues to rise until it reaches the surface or meets some obstruction. If the obstruction is a perfectly horizontal stratum of impervious material, the progress of the oil is checked, but it does not accumulate in large bodies. If, on the other hand, the impervious stratum is inclined, the oil continues to move upward along its under side until it meets a downward bend in the bed which it can not pass. The oil is thus trapped in the fold or anticline, and if the impervious bed is continuous over the crest it continues to accumulate and an oil pool is formed. The Appalachian field is characterized by low folds, which have a general northeast-southwest trend, parallel with the large folds of the Appalachian Mountains, and these folds have been of the highest importance in the accumulation of oil in that field. In the Gulf Coastal Plain no structures are found which at all resemble the anticlines of the Appalachian field. The latter are undoubtedly due to horizontal compression of the earth's crust, but the Coastal Plain does not appear ever to have been subjected to such compression, and consequently the long, regular parallel folds are wanting. The circular or elliptical domes which have been described as occurring at Spindletop, Damon Mound, and elsewhere are structures of a wholly different class, and could scarcely have been produced by horizontal compression. Although these domes are not strictly comparable with the anticlines of the Appalachian field, they are equally efficient in furnishing the structural conditions favorable for the accumulation of oil.

SATURATION OF THE ROCKS AND CIRCULATION OF THE SATURATING FLUID.

Sedimentary rocks below the immediate surface are generally saturated with water, either fresh or saline. In some cases, particularly in the Appalachian field, the rocks are dry, and under these conditions, even when sufficiently porous, they are not readily traversed by oil. This condition, however, is probably very rarely present in the thoroughly saturated beds underlying the Coastal Plain.

GENERAL RELATIONS OF GAS, OIL, AND WATER.

In most oil fields both gas and salt water are found. Many wells yield all three, either at the same time or in succession. A knowledge of their mutual relations is important, not only in the proper management of a single well, but in the exploitation of a field as a whole. Where any two of these fluids are found in the same reservoir, the heavier is found below and the lighter above. Where all are present and free to arrange themselves according to their several specific gravities, the gas will be found above the oil and the salt water below. These conditions are shown in the accompanying sketch (fig. 11). The well A taps the top of the reservoir and yields only gas; the well B, on the side of the reservoir, penetrates only oil-bearing rock and the oil is forced upward by the downward pressure of the overlying gas; the well C penetrates the reservoir rock below the lower limit of the oil, and hence yields only water, which may or may not flow at the surface.

These simple theoretical conditions imply that all the oil, gas, and water are contained in a single reservoir whose roof contains no subordinate arches or domes. Under these circumstances a light fluid borne up by a heavier will be gathered into a single body at the top of the reservoir. In actual occurrence such simple cases are exceptional and the distribution of the three fluids is sometimes complicated, yet the principle is very important. Wells frequently yield gas at first and oil later, on account of the pressing up of light fluids by the heavier. The appearance of salt water in a well after the exhaustion of the oil is a common occurrence.

NATURAL FLOW.

When oil is struck, it usually rises in the well. It may even overflow or be expelled with great violence. Two theories have been employed in explaining the pressures necessary to these phenomena, the gas-expansion theory and the hydrostatic theory.

The gas-expansion theory assumes, as the one essential condition, that the gas and the oil are confined under pressure in the same reservoir. It matters little whether the gas be above the oil or absorbed by the oil on account of the pressure. In either case the expansive pressure of the gas may expel the oil when the latter is tapped by a well.

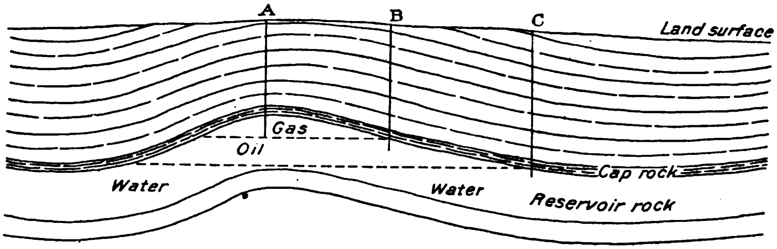

FIG. 11.—Theoretical relations of gas, oil, and water in the reservoir rock.

According to the hydrostatic theory, the gas, oil, and water are arranged in the subterranean reservoir in the order of their specific gravities, the gas being on top and the water at the bottom. The water is assumed to saturate the porous stratum continuously from beneath the oil reservoir to the outcrop and to transmit the pressure, due to the greater elevation of the outcrop, to the overlying oil. A close correspondence was found by Orton between the closed pressure of wells in the Trenton field of Ohio and Indiana and the weight of a column of water equal to the difference in elevation between the well head and the Trenton outcrop. Even in this region, however, which is the one commonly cited in support of this theory, there are certain cases of exceptionally high and low pressures which it does not explain. It also fails to explain the extreme range in pressure observed in the Texas-Louisiana field in different parts of the same pool, and, further, it is inconsistent with the behavior of the wells when flowing (see p. 123).

GEOLOGIC RELATIONS OF THE GULF COASTAL PLAIN OILS.

In the preparation of this report the geologic relations of the oil have been kept constantly in mind. So far as possible they have been described concretely for each field. The following more general statement should be read in the light of the facts thus given in detail. Some repetition is inevitable in summing up the facts and making the generalizations.

The accumulation of oil in the Coastal Plain sediments is, in several respects, in strong contrast with the corresponding process in parts of the Appalachian field. In the latter case the reservoir rock, the cap rock, and the formation from which the substance of the oils is believed to be derived are all continuous, without important change of character, over thousands of square miles. The relation of each to the oil is so definite that if, at any place, the age and folds of the underlying rocks be ascertained, the conditions with respect to oil are to a considerable degree known. On the Coastal Plain not only are dips and folds difficult to determine, but the age of a bed gives no clue to its physical character or its relation to oils, if present. Stratigraphy is therefore relatively less important in the study and exploitation of oil in the Coastal Plain fields than in fields of the Appalachian type.

SOURCE OF THE HYDROCARBONS.

Most of the sediments of the Coastal Plain contain small quantities of petroleum. The amount thus disseminated is extremely large, perhaps larger than that which has accumulated into bodies of commercial importance. The distribution is so general that it would be impossible to name any one formation, or any series, as the probable source of the original hydrocarbons. The distribution of oil in very small quantities through hundreds or even thousands of feet of sediment, much of which is highly impervious clay, might be supposed to give plausibility to the assumption of its origin within the beds where it is now found. On the other hand, the enormous quantities found in certain small pools are inexplicable on any such hypothesis.

MOVEMENTS.

The collection of hydrocarbons into reservoirs of oil is related to the presence of water in at least two ways: (1) The oil is buoyed up by the ground water; (2) the oil must share to some extent in the movements of the water until the former comes to rest under an impervious arch or dome. These statements apply to oil as a liquid lighter than water, but the nature and condition of the hydrocarbons previous to their accumulation as oil are unknown.

EFFECTS OF IRREGULAR BEDS?

Being buoyed up by the ground water, the oil should rise through the sands of the Coastal Plain sediments until a bed of clay is reached. If porous and impervious beds were here regular in thickness and character, like those in the Appalachian fields, and were similarly folded, the oil would travel to the crests of the anticlines and accumulate in long, narrow pools. The beds of this region are, however, most irregular. No two well sections, even if closely adjoining, exactly correspond. In Ohio alone the Berea sandstone extends over 15,000 square miles with scarcely any variation in thickness and composition. In the Coastal Plain, on the other hand, no single bed can be traced without material modification over 100 square miles. Clay beds graduate laterally into sands, and vice versa. Under these conditions the small coastward dip of the sediments is practically negligible in comparison with the much steeper slopes formed by the irregular distribution of sands and clays. A large number of sand beds fortuitously distributed may touch, forming a single body, whose effect on the movements of ground water is that of an inclined stratum. This condition is illustrated in fig. 12, in which the bedding planes are assumed to be horizontal, though bodies of porous and impervious sediments are distributed in such a way that the movements of ground water are along steep slopes.

Not only are such slopes as are here described generally much steeper than the dips, but they conduct the oil now in one direction and now in another, so that the course pursued by the rising fluids may be inconceivably devious and the vertical component of the resulting movements very large. The lower surfaces of the clay bodies, taken as a whole, are irregular, and do not offer continuous slopes. The oil in its upward movement finds innumerable small pockets or traps in which it comes to rest. It may finally reach the surface and cause "surface indications" or it may accumulate in the sands in bodies of commercial importance as at Saratoga and Jennings.

ACCUMULATION AT SPINDLETOP.

It is not impossible that the extraordinary pool at Spindletop may have originated by the coming together of oil originally disseminated, but if so, the oil must have traveled very long distances laterally, or the lower sediments in that vicinity must have had a peculiar composition. It is probable that the quaquaversal dip from Spindletop extends but a short distance beyond the limits of the oil field (see p. 36). If so, the structural slopes, which guided the oil to the pool, must have been due to the irregular distribution of porous and impervious sediments. That such slopes, whose very existence is due to irregular distribution, should be continuous for miles without a break in the impervious cover is remarkable. It is no less surprising that so large a proportion of the oil should have reached the central reservoir instead of being detained in pockets by the way (see fig. 12). As pointed out below (p. 120), there are some indications of an upward movement of ground water in the mounds and oil fields. This would involve lateral movement of surrounding ground waters toward the place of rising, thus aiding in the accumulation of oil. These considerations have a bearing on the question whether the Spindletop oil was independent in origin from the mound itself and simply found the mound a convenient reservoir, or whether the making of the oil was a part of the same complex process which resulted in the peculiar assemblage of minerals which underlie the mound.

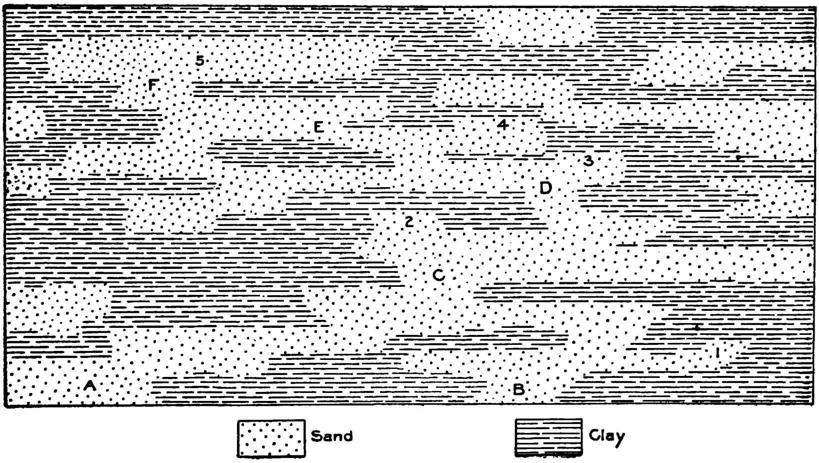

FIG. 12.—Ideal section of irregularly interbedded sands and clays. Oil may be borne up from A and B past C, D, E, and F, accumulating at 1, 2, 3, 4, and 5. The proportion of clay may be much larger than here represented and the motion of the fluids may be more nearly horizontal.

RESERVOIRS.

IN THE SAND.

The Coastal Plain oils are found in two classes of reservoirs, sands and porous limestone. In either case the impervious cover is mainly of clay. Sometimes the oil-bearing sand is overlain by a thin bed of dense limestone which is locally called the "cap." As such limestones are frequent in the clays, and are no more impervious than the clays themselves, they play no essential part in the retention of the oil. They are mentioned here merely to guard against attaching significance to them.

Where the accumulation of oil in the sands is considerable, it is necessarily prevented by impervious beds from escaping laterally as well as upward. The absence of oil from coarse, loose sands may frequently be due to the fact that it is free to escape upward around the edges of the clay cover. Where circulation is free, sands so situated become the so-called "water sands."

IN THE LIMESTONE.

The oil-bearing limestone of the mounds may be either porous or cavernous, or both. Where completely crystalline, a part of the oil is contained in the pores between the individual crystals. Not all the porous limestone contains oil. At Spindletop no limestone was found with empty caverns, while at Damon Mound, where the rock is very cavernous, no oil is found. In the Matagorda field a part of the cavernous limestone bears oil, but some fragments came to the surface perfectly clear and unstained by oil. From this evidence and from the high degree of independence among wells (compare pp. 60, 122) it may be inferred that the oil-bearing limestone varies greatly from place to place in the amount of pore space, that it comprises a group of small reservoirs or compartments rather than a single large one, and that neighboring compartments in the same "pool" may be entirely without communication.

Beneath the reservoirs in the sand are generally thick clays, and beneath the porous limestones are various impervious formations, among which clay, marl, and gypsum are common. In no case can it be shown that the beds beneath the oil are less impervious than those above. It is necessary to assume either that the oil entered the reservoir from the sides or that, previous to its accumulation as an oil body, the substance of the oil existed in some form in which it was able to traverse clay more rapidly than at present.

MOVEMENT OF GROUND WATER IN THE MOUNDS.

A number of phenomena seem to indicate local upward movement of the ground waters of the Coastal Plain. These phenomena are more frequent in or near the mounds and oil fields than elsewhere.

SALINITY.

One evidence of vertical circulation lies in the distribution of fresh and salt ground waters. It may safely be assumed that, in general, the movement of coastal-plain ground waters is coastward and that this water is supplied by rain on the land. Therefore when a coastal plain has been long out of water, the salt water originally contained in the sediments will be replaced by fresh water. At great depths salt water may persist longer. Drilling has shown that the water may be fresh to a depth of more than 1,000 feet. That which came from the bottom of the Galveston well (3,070 feet deep) was only brackish. The water from a depth of 100 or 200 feet at Sour Lake or Batson is quite as salt as that which came from 3,000 feet at Galveston. With greater depths the salinity rapidly increases. Even a mass of salt such as underlies Spindletop could not produce this local effect without an upward circulation.

The frequent proximity of salines or salt marshes to oil fields has been remarked by Mr. Lee Hager.[a] The perennial dampness of many such spots is believed to be due to rising waters.

TEMPERATURE.

The temperature of waters in or near the oil fields is frequently much higher than the normal for the depth from which the water comes. Most observations of well temperatures in the oil fields have been made under conditions which did not insure accuracy, but there is general agreement in the testimony. The normal ground temperature at a depth of 30 feet at Batson is about 74° F. Adding 1 degree for each 50 feet of additional depth the temperature at 1,000 feet should be about 93° F. Temperatures of 116°, 122°, and 126° are reported at Batson. Wells several miles from the field report even hotter waters. A temperature of 180° is reported from a well near the Saratoga field. Matagorda had a strong artesian flow of sulphur water at a temperature of 99¾° from a depth of 700 feet. Various wells at Sour Lake and Jennings showed temperatures above 100°. In some fields, as at Jennings, it has been observed that abnormal temperatures were not encountered above the oil, but came in suddenly when wells were drilled deeper.

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[a] The mounds of the southern oil fields: Eng. and Min. Jour., July 28, 1904, p. 137.

THE WORK OF RISING GROUND WATERS.

Both the abnormal temperatures and the abnormal salinity suggest upward movements of ground waters. Future study may perhaps show that ground waters have been concerned in making the salt and gypsum of the mounds, as well as the crystalline limestone, whose origin has already been explained (p. 16). It may even appear that the pressure exerted during the growth or alteration of these bodies was sufficient to raise the mounds. The agency of circulating waters in the accumulation, not only of the oil in the Coastal Plain pools, but also of the associated sulphur, dolomite, and salt, has been suggested by Hill.[a]

> The hypothesis is as follows: The oil and salt pockets of the Texas Coastal Plain are probably not indigenous to the strata in which they are found, but are the resultant products of columns of hot saline waters which have ascended, under hydrostatic pressure, at points along lines of structural weakness through thousands of feet of shale, sand, and marine littoral sediments of the Coastal Plain section, through which oil and sand[b] are disseminated in more or less minute quantities. The oil, with sulphur, may have been floated upward on these waters, and the salt and dolomite may have been crystallized from the saturated solution.
>
> The channels of these ascending waters may have been in places of structural weakness, such as fissures, which probably at one time continued to the surface, but may have been sealed by the deposition of the later overlapping strata now capping the oil pools.

Many facts may be adduced in support of this hypothesis, although it must be admitted that it presents some serious difficulties. The mode of accumulation of the enormous masses of rock salt which occur in the Louisiana Salt Islands, in Damon Mound, in High Island, and also in Spindletop, has never been satisfactorily explained. For a variety of reasons it does not seem possible that they can be the result of evaporation of sea water in natural salt pans, which is supposed to be the origin of most deposits of rock salt. It may therefore be necessary to refer their origin to precipitation from rising ground waters, though no plausible reason has yet been suggested for the precipitation of the salt.

The spot at which the ground water rises may be determined by the absence of a continuous clay cover or by a small fault. In either case any oil brought up would escape so long as the vent remained open to the surface. If the vent were subsequently sealed by the deposition of impervious beds, the oil might collect in a pool. It has been suggested as a possible explanation of the difference between the oil-bearing mounds like Spindletop, on the one hand, and those barren of oil like Damon Mound and the Salt Islands, on the other, that the vents of the former were thus sealed after the salt had been deposited, while those of the latter had remained open.

RELATION OF THE OIL TO GAS AND SALT WATER.

GAS.

Gas may be encountered at any depth, either with or without the oil. That found above the oil, or in fields where no oil is found, is commonly called "dry gas." If this be allowed to escape it sometimes happens that a spray of oil begins to show in the gas after a few hours or a few days. This points to some communication between the reservoirs of gas and oil. Much gas is so closely associated with the oil that the two issue simultaneously. This is the "poisonous gas" of the gushers. In the reservoirs it is probably contained in the oil under pressure instead of accumulated above it. Gas is also frequently found beneath an oil body. This phenomenon of a lighter fluid beneath a heavier indicates that the two are separated by an impervious bed.

SALT WATER.

Salt water occurs both above and below oil bodies. Two or three alternations may be found, each water horizon being separated from the next underlying oil by a bed of clay.

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[a] Hill, R. T., The Beaumont oil field, with notes on the other oil fields of the Texas region: Jour. Franklin Inst., 1902.

[b] It is probable that this word "sand," which appears in Mr. Hill's original paper, should have been "salt."

In some cases the two fluids are contained in the same reservoir, the salt water gradually replacing the oil at the top of the reservoir as the oil is pumped out or expelled by gas pressure.

INDEPENDENCE AMONG WELLS.

Neighboring wells in the limestone show by their behavior a large degree of mutual independence. To a less degree this is true of wells in the sands. The depths of wells in the limestone vary greatly within short distances. One well may produce oil, and a deeper well near by may yield only gas, or a shallower one may be yielding salt water. The behavior of the same well at different times may be still more strange. A few wells have gone entirely to salt water and, after days or weeks, have begun again to yield oil in large quantities. In some cases the later yield was pure oil with no water. These phenomena of independence among wells and of abnormal behaviors are due to the subdivision of the reservoir into many compartments. Communication among these compartments is of all degrees of freedom. Some of them may be entirely sealed. A number of small rooms may be drained by the same well, either simultaneously or successively. One room may contain mainly oil, another mainly gas, or a single room may contain all three fluids. These conditions are sufficient to account for all apparently abnormal phenomena.

WELL PHENOMENA.

LOSS OF WATER.

In drilling by the rotary process it may occur at any time that the water being pumped into the well suddenly fails to reappear. This is called "losing the water." It indicates that a porous stratum has been entered. The nature of the rock can not be determined except by the behavior of the tools, for without a return flow no samples are obtainable. The failure to get a return of the water does not necessarily prevent further drilling, for, in its escape into the porous or cavernous rock, it may, for a time, at least, carry with it the cuttings and thus keep the bottom of the hole clear. If the uncased part of the hole does not cave the working of the tools is not interfered with. The continued pumping in of "slush" (often thickened under such circumstances) may sufficiently choke the pores by which the water has escaped to restore the return flow, or the porous bed may be drilled through and cased, allowing the drilling to go on as before.

This sudden loss of water may occur in the sands above the oil rock, but at Spindletop it was more frequent at the horizon of the latter. It is not to be understood that when water is lost the porous bed into which it is passing is either dry or lacking in gas pressure. It may bear water, oil, or gas. The sinking of the column of water in the drill pipe merely indicates that the fluid pressure within the rock is less than that of the column in the well. Therefore, if the well be bailed, it may blow out or gush, the oil being brought up as a spray, or it may be a good pumping well. Under the conditions which allow the water to be lost it must not be expected that the well will flow either water or a solid stream of oil.

SUDDEN DROPPING OF TOOLS.

A phenomenon sometimes associated with the loss of water (though either may occur independently) is a sudden dropping of the drilling tools. Frequently such a drop is reported as 3 or 4 feet, or even twice that amount, though doubtless the reports are exaggerated. Such drops are generally believed by drillers to indicate great cavities. Small drops while drilling in the limestone may, indeed, be so explained, but in many instances a cavity in the limestone can not be assumed. Many drops are reported as occurring in a sand just below a hard plate of limestone. The drill may have worked hours and perhaps days on the thin limestone, a strong current of water all the time washing the bottom of the hole. This current may have access by a fracture to the underlying sand and wash out a great cavity in the latter before the drill has passed through the limestone. The tools then drop. It will be observed that sand, in which the drop so frequently occurs, is a poor substance to support large cavities. Probably in most cases it is not necessary to assume a cavity, but a quicksand produced by continued injection of water. A sudden loss of water may follow the drop of the tools.

WELL PRESSURE.[a]

[The phenomenon of gushing, so common in all the large fields of the Coastal Plain, implies great pressure.] In some cases it has shown almost explosive violence, blowing out casing and breaking heavy cast-iron valves. The maximum pressure has never been even approximately measured. Some closed pressures of 500 pounds and over per square inch have been reported, but these are not well vouched for. The reliable measurements vary from 79 to 350 pounds.

The following are the most trustworthy measurements which have been made of closed pressure:

Measurements of closed pressure of oil wells in Gulf Coastal Plain field.

	Pounds.
American Oil and Refining Company	79
Texas Oil and Pipe Line	112
Trans-Mississippi	300
Yellow Pine	340
San Jacinto No. 1	350

The Hooks well at Saratoga showed a steady closed pressure of 127 pounds.

* * * * * * *

It appears highly probable that the pressure in the oil reservoir is due largely to the expansive force of the associated gas. When the oil rock is penetrated by the drill it is usually, though not always, necessary to remove the water from the casing by bailing. When the pressure is thus relieved there is first a rush of gas, followed by a stream of oil, which is expelled with great violence. The oil, however, never flows in a steady stream like the water from an artesian well, but by a series of jets or pulsations. These may be relatively slow, each flow of oil lasting for several minutes, followed by an equal or longer period of quiescence, in which only gas escapes; or they may be rapid, several pulsations occurring within a single minute. The rapidity of the pulsations appears to depend, among other things, upon the depth to which the well is drilled into the oil rock; and their rapidity, and consequently the yield of the well, is generally increased by deeper boring. It is also probably influenced by the character of the oil rock, the more porous rock yielding its contained oil more rapidly than that which is relatively compact. In addition to this longer period the stream of oil generally shows a very rapid pulsation similar to that observed in a jet of mingled water and steam when a boiler is blown off.

A common method of raising oil in wells which do not flow is to carry air under high pressure to the bottom of the well by means of a small pipe within the casing. When the air is turned on and accumulates sufficient pressure to lift the column of oil in the casing, the oil is expelled in a pulsating stream exactly similar to a natural gusher. In the one case, however, the expansive force of artificially compressed air is the expelling force, and in the other case it is the expansive force of the naturally compressed gas which is associated with the oil in the rock reservoir.

In addition to the expansive force of the gas, there is also probably some hydrostatic pressure in this field, but its influence in producing the phenomena of a gusher must be relatively insignificant. Quite generally throughout the Coastal Plain region an artesian water flow is obtained at depths ranging from 600 to 1,500 feet, but this has only a very moderate head. This is seen in the 1,400-foot artesian well at the Beaumont court-house, where the head is only a few inches above the surface. [The invasion of wells by salt water is, doubtless, in some cases, due to hydrostatic pressure; in other cases it is due to gas pressure.] * * *

If the pressure to which the gushing in the Spindletop and other Coastal Plain pools is due is chiefly the expansive force of gas, it follows that this force will expel only a part of the oil, and the remainder will necessarily be won by pumping or by supplying the place of the natural gas by compressed air. [This has already been demonstrated in the case of Spindletop, where gushing ceased in 1903.]

SURFACE INDICATIONS.

The surface indications which have led to the exploiting of the several fields are various. They may be divided into two classes—those which are common to oil fields in general, and those which owe their significance to the peculiar relations of the Coastal Plain oils. Almost all surface indications depend on a circulation of fluids. The lines of such circulation through the sediments of the Coastal Plain have been shown to be very devious (see fig. 12, p. 119). A seepage at the surface, therefore, does not indicate the exact location of an oil body. The two may be miles apart. Usually surface indications are scattered throughout an area which is many times that of the oil pool. Very abundant seepage of oil or gas may result from the want of an impervious cap or of domed structures which would make accumulation possible. It is, therefore, by no means to be inferred that the escape of a large amount of gas is a better indication than that of a small amount. Indeed, the best fields of the Coastal Plain have been marked by very modest indications.

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[a] Revised and reprinted from Bull. U. S. Geol. Survey No. 212.

INDICATIONS COMMON TO OIL FIELDS IN GENERAL.

Of the indications common to this and other fields, a seepage of oil is the best. This evidence has been found in a considerable number of the Coastal Plain fields. It may, however, be confused, as it frequently has been, with another phenomenon which bears no relation to oil—the appearance of an iridescent scum of iron oxide on stagnant water in regions where the soil is strongly colored with limonite. This phenomenon is very common in the red soil districts of eastern Texas. Closely related to a seepage of oil is the asphaltic substance sometimes found impregnating the soil at shallow depths. This evidence is not so widespread as are the oil seepages in the Coastal Plain. It is well illustrated at Anse la Butte, Sour Lake, and the "Tar Springs" of Jasper County, Tex. The "sea wax" of the Gulf coast belongs to the same class of phenomena (see p. 77). By far the most common of all evidences is the escape of gases. Indeed, this phenomenon is so widespread that it is entirely unsatisfactory as an indication of the place where drilling should begin. In this, again, the phenomena of importance are frequently confused with those which have no significance whatever. To the latter class belongs the escape of marsh gas from recently buried sediments. A very simple distinction, having some significance, is that based on the leaving of an oily film on the water after the breaking of a bubble. The leaving of such a film may be regarded as evidence that the gas contains petroleum vapor and may therefore suggest the presence of oil at the place from which the gas came. It must, however, be remembered that on the one hand there is much "dry gas" even in the oil fields, and on the other hand the quantity of oil whose presence is thus indicated may be very small.

INDICATIONS BASED ON LOCAL CONDITIONS.

Some significance is attached to a number of phenomena on observational grounds alone, their relation to oil not being satisfactorily explained. Of this class of surface indications the escape of hydrogen sulphide probably deserves the most consideration. At places the bubbling up of the gas itself through stagnant water is all that is to be seen. At other places the waters have become more or less strongly sulphureted. In some districts, around the mouths of shallow wells, an incrustation of pure sulphur is continuously forming. Closely related to the escape of this compound of sulphur are the so-called "sour waters." These are best known at Sour Lake, but are by no means uncommon. Their salts are largely sulphates, and their significance may be similar to that of sulphureted hydrogen, all being members of a group of substances which are related in origin.

A phenomenon which has carried far more weight than justly belongs to it is found in the so-called "gas mounds." These are low, rounded mounds, averaging perhaps 2 feet in height and several rods in diameter. In view of their vast numbers on the flat Coastal Plain, they show remarkable uniformity in size and shape. They are popularly supposed to be connected with the escape of gases from the soil. Whatever be their origin, there is as yet no evidence that they are in any way related to oil bodies. Even were such a relation assumed, these mounds are so widely distributed over the flat Coastal Plain, that as guides to drilling they are of no value whatever.

On the uneroded parts of the Coastal Plain, by far the largest significance has very justly been attached to low mounds of the Spindletop type. No oil has been found in the higher mounds. Since the surficial elevation must be regarded as merely incidental to the geologic structure, and since the most abundantly oil bearing of all (Spindletop) is but 10 feet high, it is highly probable that the characteristic structure and materials exist at many spots not marked by an elevation. The chance of finding these materials under elevated spots is however, vastly greater than elsewhere.

There is some reason for thinking that such structures are ranged along lines of slight crustal deformation or disturbance. If such lines exist, they probably trend northeast and southwest. This probability may well be recognized in prospecting for new fields.

PHYSICAL AND CHEMICAL PROPERTIES OF THE TEXAS-LOUISIANA OIL.[a]

PHYSICAL PROPERTIES.[a]

COLOR AND ODOR.

When flowing from the well or first received into the tank, the Beaumont petroleum is a dark reddish-brown fluid, carrying a large quantity of hydrogen sulphide in solution. It has a very strong, disagreeably pungent, sulphurous odor, attacking the mucous membranes of the nose and causing the eyes to smart. The Saratoga and Jennings oils are somewhat darker and heavier, and, owing to the smaller quantity of gas which they contain, have a less disagreeable odor. The small quantity of oil flowing from the Equitable Mining Company's well at Columbia is also of a very dark color [and is, in its natural state, a good lubricant].

Upon exposure to the air these oils gradually lose a large proportion of their contained gases and become somewhat thicker and darker. They do not, however, lose their peculiar odor. Kast and Lagai attribute the odor of petroleum to the presence of unsaturated hydrocarbons, while Mabery and Smith appear to think it is due to a mixture of bad-smelling compounds, but do not say what may be the cause, although they found unsaturated hydrocarbons in their experiments with the Ohio oils.[b] Richardson[c] also found considerable quantities of unsaturated hydrocarbons in the Beaumont oils.

SPECIFIC GRAVITY.

The specific gravity of the Beaumont petroleum ranges from 0.904 to 0.925, or 25.4° B. to 21.5° B. [The early tests of the Sour Lake oil gave it specific gravities of 0.945, 0.958, and 0.963, or 18° B. to 15° B., but the oils found later are lighter, and the average gravity of oil from this field is about equal to that of the Spindletop oils. The Saratoga oil has a specific gravity of 0.945, or 18° B. The deeper Batson oil has a gravity of 27° or even 28° B. That from shallow wells is heavy.]

A comparison of the specific gravities of the petroleum from various districts of the Coastal Plain with those of other well-known fields shows the former to be much heavier than any of the petroleums which contain a notable proportion of illuminants. They are, however, in this respect similar to the Calfornia oils. Some of the Mexican oils are also heavier.

Specific gravity of petroleum from various fields.

Pennsylvania[d]	0.801–0.817
Ohio (Lima field)[d]	.816– .860
Kansas[e]	.835–1.000
West Virginia[d]	.841– .873
Canada (Petrolia field)[d]	.858
Russia (Baku field)[d]	.859– .871
Mexico[d]	.874– .970
Beaumont[f]	.904– .925
Wyoming[d]	.912– .945
California[g]	.920– .983
Saratoga (Hooks No. 1)[h]	.937
Sour Lake[i]	.945– .963
Brazoria County, Tex.[h]	.965
Borneo[d]	.965

FLASH AND BURNING POINT.

A roughly approximate ratio exists between the specifie gravity of any petroleum and its flashing point, and as a general rule a low specific gravity accompanies a low flashing point, and while the burning point of an oil is usually from 10° to 15° higher than the flashing point, this is not always the case. An oil having a high flashing point always has a high burning point, but, on the other hand, a high burning point may be accompanied by a low flashing point.

The flashing test of an oil is made for the purpose of determining the lowest temperature at which it gives off an inflammable vapor, and is the most important test which can be applied to any petroleum, since it is to the inflammable vapor evolved at ordinary temperatures that most of the accidents are due.

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[a] Reprinted with slight revision from Bull. U. S. Geol. Survey No. 212.
[b] Am. Chem. Jour., vol. 16, p. 88.
[c] Jour. Soc. Chem. Industry, vol. 20, p. 693.
[d] Redwood, Petroleum and its Products, 1886, vol. 1, p. 178.
[e] Hayworth, Mineral Resources of Kansas, 1897, p. 51.
[f] Jour. Soc. Chem. Industry, vol. 20, p. 691 et seq.
[g] Watts, Oil and gas: Bull. Cal. State Mining Bureau No. 19, p. 204.
[h] Worrell, analyst, Texas Mineral Survey.
[i] Jour. Soc. Chem. Industry, vol. 19, p. 122.

This point is quite independent of the burning point and depends altogether upon the character and amount of the volatile constituents, while the burning point depends upon the character and composition of the oil as a whole.

The presence of the lighter hydrocarbons lowers the flashing point, since these volatilize more readily than the heavier hydrocarbons. The effect of benzine in varying proportions in lowering the flashing point, as determined by Wilson,[a] is shown in the following table:

Effect of mixture of benzine on flashing point.

	Flashing point.	Burning point.
	°*F.*	°*F.*
Oil alone	118	135
Mixed with—		
1 per cent benzine, 65° B	112	129
3 per cent benzine, 65° B	103	123
5 per cent benzine, 65° B	96	116
10 per cent benzine, 65° B	83	102
1 per cent benzine, 72° B	107	133
5 per cent benzine, 72° B	70	105

Very few tests of the Coastal Plain oils have been made with the view of determining either their flashing point or their burning point, and the few made show very discordant results. The differences are probably due, in part at least, to the different length of time during which the various samples had been exposed to the air, with consequent evaporation of the more volatile constituents.

Flashing point and burning point of Beaumont oil.

Determined by—	Flashing point.	Burning point.
	°*F.*	°*F.*
Ledoux[a]	165	....
Richardson[b]	110	....
Emery	110	180
Denton[c]	142	181
Oliphant[d]	180	200

[a] Trans. Am. Inst. Min. Eng., vol. 31, p. 370.
[b] Jour. Soc. Chem. Industry, vol. 20, p. 691.
[c] Report to Export Oil and Pipe Line Co.
[d] Mineral Resources U. S. 1890, p. 580.

It appears from the above that in the use of this oil in its crude state no danger need be apprehended from fire due to the generation of inflammable gases if its temperature is kept below 110° F., and that by the gradual escape of the lighter hydrocarbons the temperature at which dangerous gases are given off rises in a comparatively short time to 180°, or even higher. This conclusion is amply confirmed by a series of experiments made by Professor Denton to determine this point.

VISCOSITY.

The physical character of petroleum is more or less affected by low temperatures. Some experiments made with the Saratoga oil show that prolonged cold has but a slight effect upon it. A test tube filled with the crude oil was submerged in the freezing tank of the Austin Ice Factory for sixteen hours. The temperature of the tank at the time of immersion was 22° F., and at the close of the experiment the temperature had risen to 26° F. Another test tube was surrounded by a freezing mixture so as to reduce the temperature of the oil to 10° F., and it was kept at this for half an hour. In both cases the oil showed only a slight thickening and did not run as freely as at ordinary temperatures. Other experiments made by Ledoux, Emery, and Denton have shown that the Beaumont oil remains liquid at 10° F.

The viscosity of the Beaumont oil, according to the Pennsylvania Railroad standard, is 77 seconds as compared with 42 seconds for the Pennsylvania and 37 seconds for the Noble, Ohio, oils.

CHEMICAL PROPERTIES.

Our information regarding the chemical properties of the Texas-Louisiana oils is derived chiefly from the work of Messrs. Thiele, Mabery, and Richardson, whose results and conclusions are given below.

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[a] Crewe, Practical Treatise on Petroleum, 1887, p. 359.

The properties investigated include ultimate composition, volatility, products of fractional distillation, viscosity of residues, specific gravity, and refractive index of distillates. For the purpose of comparison, determinations of the same properties in oils from other fields are also inserted.

COMPOSITION.

The ultimate chemical composition of the Beaumont and Sour Lake oils as compared with oils from other fields is given below.

Ultimate composition of various oils.

[Per cent.]

	Beaumont.		Sour Lake.[a]	Pennsylvania.[a]	Ohio.[a]	California.[b]
C	[a] 85.03	[c] 84.60	85.96	86.10	85	84
H	12.30	10.90	13.97	13.90	13.80	12.70
S	1.75	1.63	....	.06	.60	.40
O, N	.92	2.87	....	....	.60	2.09
Loss on treatment with excess of H_2SO_4	39	....	....	21	30	....

[a] Jour. Soc. Chem. Industry, vol. 20, pp. 161 et seq.
[b] Salathe, Bull. Cal. State Mining Bureau No. 19, p. 207.
[c] Rept. Liquid Fuel Board, U. S. Navy, 1902, p. 69.

The sulphur content of the Beaumont petroleum is high and it also carries a large amount of hydrogen-sulphide gas in solution. This gas largely escapes on standing, and is more completely expelled if air or steam is blown through the oil. After such treatment Richardson found the oil to contain 1.75 per cent of sulphur. Mabery found 2.16 per cent; Denton found 1.63 per cent; O. H. Palm found the Higgins oil to contain 2.4 per cent of sulphur, and A. M. Smoot found the oil from the Lucas well to contain 2.04 per cent.

According to Mabery,[a] the Ohio oils have 0.50 per cent of sulphur, while the Canadian oils contain, according to the same authority, 0.98 per cent. Orton and Lord[b] found 0.553 per cent in the Trenton limestone oils.

The condition in which this sulphur exists in the petroleum is an important question from the technological standpoint, since it will determine the methods to be adopted for its removal. Considerable light is thrown on the question by experiments in the fractional filtration of this oil, carried on by Dr. D. T. Day, and described at the Petroleum Congress in Paris in 1900.

The oil from which the hydrogen sulphide had been removed by a current of air was passed through a filter made by packing kaolin in a glass tube 19 inches in length. The oil entered the bottom of the tube under a head of 56 inches and passed through very slowly, only 5 cubic centimeters having passed in the first twenty-four hours.

The color, odor, specific gravity, and sulphur content of the several fractions obtained in this manner are given below.

Filtration products from Beaumont oil. [a]

	Amount in c. c.	Color.	Specific gravity at 25° C.	Sulphur.	Remarks.
				Per cent.	
Crude oil	....	Deep brown	0.914	1.75	Rank odor.
First fraction	5	Water white	.8755	.80	Sweet odor.
Second fraction	21	Pale lemon	.8986	.91	Do.
Third fraction	8	Deep lemon	.9038	1.04	Do.
Fourth fraction	22	Amber fluorescent	.9068	....	Do.
Fifth fraction	10	.....do	.9104	....	Do.
Sixth fraction	22	Deep amber	....	....	Do.
Seventh fraction	13	.....do	.9115	....	Do.
Eighth fraction	20	.....do	.9115	....	Do.

[a] Jour. Soc. Chem. Industry, vol. 21, p. 317.

On standing for a month or more the denser fractions, and especially the second, deposited beautifully regular crystals of sulphur. These could only have been derived either from the decomposition of sulphur compounds while passing through the filter or from sulphur existing as such dissolved in the oil. The latter appears the more probable, although further investigation is required to settle the question definitely.

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[a] Am. Chem. Jour. 1891, vol. 13, p. 234.
[b] Eighth Ann. Rept. U. S. Geol. Survey, pt. 2, 1889, p. 625.

VOLATILITY.

The volatility of the Beaumont petroleum as compared with oils from Noble County, Ohio, and the Pennsylvania pipe lines is shown by Richardson to be as follows:

Relative volatility of Beaumont oil.

	Sour Lake.	Beaumont No. 1.	Beaumont No. 2.	Noble County, Ohio.	Pennsylvania pipe lines.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
110° C. (230° F.), 7 hours	....	19.19	20	41.2	47.3
162° C. (325° F.), 7 hours	....	31.31	27	43	58
205° C. (400° F.), 7 hours	35	57.57	49	59	68
To constant weight.					
105° C. (221° F.), 42 hours	....	48	48	48.7	58
162° C. (325° F.), 70 hours	....	[a] 64	57	61	[b] 71.8
205° C. (400° F.), 49 hours	....	74	74	75	84

[a] Forty-nine hours.

[b] Forty-two hours.

The distillation as carried on in Engler's flasks gave the following results:

Distillation of Beaumont oil.

	Sour Lake.	Beaumont.	Ohio.	Pennsylvania.	California.[a]	
Distillation begins ° C.	....	110	85	80	....	
Below 150° C per cent.	....	2.5	23	21	....	7.6
150°-300° C do.	6.6 [b] 12.7	40	21	41	14.2	33.8
300°-350° C do.	2.6	20	21	14	5.2	6
350°-400° C do.	....	25	27	23	....	
Loss on acid treatment do.	....	10	5	1.8	....	
150°-300° C. fraction:						
150°-260° C do.	....	30	....	....	....	
Loss on acid treatment do.	....	8	....	....	....	
Percentage of acid used	....	7	2.5	2	....	

[a] Bull. Cal. State Mining Bureau No. 19, p. 203.

[b] Cracking begins. Residue in Sour Lake oil, 78.1 per cent.

The percentage, specific gravity, and refractive index of the fractional distillates from the Beaumont oil, as determined by Richardson, are as follows:

Fractional distillates.

	Fractions.		Distilled.	Specific gravity at 26° C.	Refractive index at 26° C.
	° F.	° C.			
			Per cent.		
Atmospheric pressure	300-401	149-245	1	0.8114	1.459
Do	401-441	205-227	8.4	.8408	1.461
Do	441-480	227-249	4.4	.8569	1.467
Do	480-520	249-271	10.8	.8705	1.476
Do	520-559	271-293	10.8	.8863	1.485
Do	559-602	293-317	13.1	.9009	1.492
20 millimeters pressure	392-464	200-240	13	.9184	1.505
Do	464-536	240-280	8.8	.9349	1.514
Do	536-608	280-320	10.6	.9429	1.521

Residue, slow flow at 70° F.

The viscosity of the residues from the open-dish evaporation of the Beaumont oil is as follows:

Viscosity of residues of Beaumont oil.

7 hours at 205° C. (400° F.)	Quick flow.
49 hours at 205° C. (400° F.)	Solid.

Penetration, 8°-10°.

A similar but softer pitch made by boiling the crude oil for twenty hours in an open dish had the following properties compared with a D grade residue or paving asphalt from Los Angeles oil:

Character of residues of Beaumont and California oils.

	Beaumont.	California.
Penetration	78°	78°
Specific gravity	0.9943	0.9964
Bitumen soluble in 88° naphtha per cent	78.3	74.4
Bitumen soluble in 62° naphtha do	84.3	81.6
Fixed carbon do	8.7	15

Richardson has called attention to the peculiar conditions under which the sulphur exists in the Beaumont petroleums and the probability of the presence of free sulphur which might account for the variability in character of the product obtained on varying the conditions under which the oil is heated, the amount of hard residue reaching in some cases to no more than 10 per cent and under other conditions to as much as 35 per cent.

Distilled in vacuo at a point where boiling ceased to go on without cracking, one of the samples from Beaumont gave distillates better suited for examinations as to the character of the hydrocarbons which make up the oil than those from the Engler flasks. Comparisons of the distillates from Corsicana, Sour Lake, and California oils show that the Beaumont petroleum is more closely related, as would be expected, to the Sour Lake than to the other oils.

Specific gravity of fractions boiling between 100° *and* 175° *C.*

	100°-150°.	150°-175°.
Beaumont	0.8637	0.8863
Sour Lake	.8693	.9056
Corsicana	.7932	.8187
California	.9195	.9547

The specific gravity and refractive index of the Beaumont distillates as compared with those from the Ohio and Pennsylvania oils are shown as follows:

Character of distillates.

	Beaumont.		Ohio.		Pennsylvania.	
	Specific gravity.	Refractive index.	Specific gravity.	Refractive index.	Specific gravity.	Refractive index.
Below 150° C	(a)	(a)	0.7297	1.412	0.7188	1.415
150° to 300° C	0.8749	1.473	.8014	1.442	.7984	1.437
300° to 350° C	.9089	1.501	1.8404	1.468	.8338	1.462
350° to 400° C	.9182	1.508	.8643	1.481	Paraffin.	1.470
After acid treatment:						
150° to 300° C	.8704	1.473	.8006	1.443	.7791	1.438

[a] Amount too small.

The residue after distillation of the Beaumont oil amounting to 9.9 per cent of the original oil, was evaporated in an open dish to 6 per cent. It was then a brittle pitch which had the following properties:

Properties of residue after distillation of Beaumont oil.

Specific gravity		1.0454
Color		Black.
Luster		Shiny.
Structure		Massive.
Fracture		Conchoidal.
Hardness penetration		15°
Soluble in CS_2	per cent.	99.8
Organic insoluble	do.	.1
Mineral matter	do.	.1
		100.0
Soluble in 88° naphtha	do.	60
Proportion of total bitumen	do.	60.1
Soluble in 62° naphtha	do.	64.8
Proportion of total bitumen	do.	64.9
Bitumen yields on ignition—		
Fixed carbon	do.	21.13
Volatile hydrocarbon	do.	78.

CONSTITUTION.

The chemical constitution of the Texas petroleum has not yet been thoroughly investigated, but Richardson and Wallace in the article quoted above[a] reach the conclusion that it contains a large proportion of unsaturated hydrocarbons, which are removed by treatment with an excess of strong sulphuric acid and washing soda. It also contains members of a hydrocarbon series $C_nH_{2n}-2$, which, although saturated, are readily attacked by cold nitric acid. Similar compounds are found in Russian and Californian oils and in Trinidad asphalt.

Mabery and Buck[b] have also investigated the constitution of the Beaumont oil and conclude that fractions distilling between 150° C. and 300° C. contain hydrocarbons of the series $C_nH_{2n}-2$ and $C_nH_{2n}-4$.

RESULTS OF REFINEMENT.

The proportions of the several products and by-products obtained by different refineries differ. The proportions also differ from one time to another as the processes are gradually improved and adapted to the treatment of the Coastal Plain oils. The following table shows the results obtained by the United Oil and Refining Company in 1904:

Products obtained by refinement of Coastal Plain oil.

Product.	Spindletop and Sour Lake crude.	Batson crude.
	Per cent.	*Per cent.*
Gasoline	1.8	6.5
Kerosene	17.1	20.4
Solar	15.4	14.4
Lubricating	52.2	46.7
Asphalt	7.5	6.0

ASSOCIATED HYDROCARBONS.

NATURAL GAS.

Throughout the whole of the Gulf Coastal Plain, wherever any oil has been found, it is always accompanied by considerable quantities of natural gas; indeed, this form of hydrocarbon is more widely distributed than the oil, and at several localities it has been found unaccompanied by oil. Among the most remarkable of these gas wells was that at Bryan Heights, Brazoria County. At Big Hill, Matagorda County, gas was also found in enormous quantities and oil was found later a short distance away. The gas horizon was struck at 900 to 1,000 feet and the initial pressure was sufficient to blow out tools and casing and wreck the derrick. The flow from each of these wells was estimated at from 5,000,000 to 6,000,000 cubic feet per day. All efforts to control the flow of gas proved unsuccessful and they were abandoned. The flow at Bryan Heights subsequently stopped and that at Matagorda was greatly reduced.

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[a] Jour. Soc. Chem. Industry, vol. 20, 1901, p. 693.
[b] Jour. Am. Chem. Soc., vol. 22, 1900, pp. 553–556.

The composition of the gas has not been carefully investigated, but it is known to contain, in addition to the light hydrocarbons of ordinary natural gas, a large proportion of sulphureted hydrogen. Hence while the gas is inflammable and may be used with advantage under boilers standing in the open, and was so used extensively on Spindletop, it is not suitable for domestic use or where the products of combustion would be objectionable. The poisonous properties of the gas from the Spindletop gushers are due in part to the constitution of the gas itself and in part to an admixture of petroleum vapor. It is customary among drillers to distinguish between the "poisonous gas" and the "dry gas" which is not associated with the oil.

UTILIZATION OF THE GULF COASTAL PLAIN PETROLEUM.

ILLUMINATING OIL.

For several years after the opening up of the oil fields of the Gulf Coastal Plain, it was believed that the oil could not profitably be refined and used for illuminating purposes. Suitable refining processes were devised later. Before the close of 1904, $8,000,000 had been invested in refineries for the treatment of the Coastal Plain oil exclusively. The following refineries are in operation:

Refineries treating Coastal Plain oil.

Name of company.	Location.	Daily capacity (barrels of crude oil).
Gulf Refining Co	Port Arthur	8,000
Security Oil Co	South Beaumont	4,500
The Texas Co	Port Arthur	1,000
United Oil and Refining Co	Spindletop	400
Colonia Oil Co	Port Arthur	100

The proportions of various products obtained by refining have been given under the heading "Physical and chemical properties of the oil." A published statement shows that in 1904 the Gulf Refining Company shipped from Port Arthur refined products as follows:

Oil products shipped by Gulf Refining Company in 1904.

	Barrels.
Gasoline	10,993
Refined oil	433,878
Solar oil	1,029,898
Lubricants	129,339
Asphaltum oil	44,990
Asphalt	22,660
Total	1,671,758

FUEL.[a]

THEORETICAL VALUE.

The value of any fuel depends upon several considerations: Commercially, upon its location and capability of successfully competing with the other fuels that may be brought into the same market. These conditions are largely governed by the cost of production, length of haul, and cost of transportation and handling. Under certain conditions it may be possible for an inferior fuel to successfully compete and even supplant a much higher grade fuel. Thus wood has been enabled in many localities to compete successfully with coal. Under similar conditions coal has been enabled to meet the inroads of gaseous or liquid fuel in its various forms.

Technically, fuels are graded by the work they will perform. This is determined either theoretically from the chemical composition or by practical tests, and the results obtained by these two methods often vary widely. It is a well-known fact that many, if not all, coals have a calculated theoretical calorific value much greater than they really possess, as shown in their ordinary use or even as measured by a calorimeter.

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[a] Reprinted from Bull. U. S. Geol. Survey No. 212.

In the testing of fuels the heat value as determined by their chemical composition is the best method yet devised, at least for comparison of new and untried fuels. By this means their relative value as compared with other well-known fuels may be determined and some idea be gained as to their approximate commercial values. By calculating the theoretical heating power various uncertain quantities are eliminated, such as style of and condition of grates, method of setting and form of boiler, draft, and a number of other conditions which can not be rendered uniform. In the testing of liquid fuel there are the questions of the size and style of burner, quantity of steam or air, or both, admitted to fire box, and a number of other practical conditions, all of which have a direct effect on the result and greatly complicate the problem.

The theoretical value of any fuel depends upon its constituents and upon their mode of arrangement. Carbon and hydrogen are considered the essential heat producers. The other constituents being generally present in small quantities are usually disregarded, with the exception of sulphur and ash. Sulphur is generally considered as a deleterious constituent of any fuel, not only on account of its low heat power, but also on account of the readiness with which it combines with the metals in the furnace. Where fuel is intended for metallurgical purposes it is required to be as free from sulphur and sulphurous compounds as possible.

The ultimate calorific value of Beaumont petroleum as determined by Redwood is 19,388 B. T. U., and as determined by Professor Denton with oxygen calorimeter is 19,060 B. T. U., giving a mean of 19,224 B. T. U. The calorific value of Pennsylvania and Ohio crude petroleum is about 20,200 B. T. U., and that of Baku, Russia, crude about 19,500. It will thus be seen that the calorific value of the Beaumont petroleum compares favorably with that of the best liquid fuels in use.

SAFETY.

Liquid fuel, however, requires other qualifications than merely high-heating values. It must be safe for transportation, handling, and for storage. Very few petroleums as they come from the well have these qualifications. All contain a greater or less percentage of naphtha or some of the lighter hydrocarbons which have a tendency to reduce the flash point and make the oil easily inflammable. Consequently a liquid fuel to be safe should not contain any of these light inflammable oils, nor should it contain naphtha. According to Oliphant, fuel oils should have a gravity of between 20° and 25° B. (specific gravity 0.9333 to 0.9032) and a flash test of from 240° to 270° F. The Astatka, or fuel, oils of the Russian fields, have a specific gravity of 21° B. (0.928) and a flash point of about 284° F., while those of the Eastern Archipelago have a specific gravity of 0.970 and a high flash point.

The effect of a mixture of the lighter oils with the petroleums is the tendency to create an inflammable vapor in connection with their storage, which, mixed with air, becomes highly explosive. It has been found that a mixture of only 2 per cent of air with this vapor makes an explosive mixture, and that upon dilution to 4 per cent or over the mixture is harmless, although still inflammable.

The few tests of the Beaumont oils have shown them to contain a small quantity of light oil, and to have a flash point correspondingly low. The flash point as determined ranges between [illegible] to [illegible] F. for Beaumont and 244° F. for the oils from the Sour Lake shallow wells.

These oils, however, appear to be very slow in the generation of inflammable gases. Two tanks in the Beaumont fields have already been struck by lightning without any explosion or even serious fire taking place, and Professor Denton, in a series of experiments, shows that the Beaumont oil does not give rise to an inflammable vapor until heated to above 142° F. For complete safety, however, these oils should be distilled so as to remove enough of the lighter constituents to bring the flash point up to about 240°, although they have been and are now being utilized with apparently perfect safety for fuel purposes in their crude condition.

The introduction of earthen and practically open tanks, allowing the lighter products to escape [illegible] process of natural distillation, may be expected to bring them within the safety limits as to flash point without further treatment.

PRACTICAL TESTS IN STEAM RAISING.

The most thorough practical experiments, with the view of testing the full value of the Beaumont petroleum, have been made by Prof. James E. Denton, of the Stevens Institute of Technology, Hoboken N. J. These tests were made in the plant of the West Side Hygeia Ice Company, of New York. From the data thus obtained it appears that this petroleum has an evaporative power of 15.29 to 15.55 pounds of water per pound of oil used. Of the steam generated 3.1 to 4.8 per cent was used by the burner in spraying the oil. There was thus left available for use the steam from 14.74 to 15.16 pounds of water per pound of oil used. Buckwheat anthracite coal used under the same boilers evaporated from 8.75 to 9.17 pounds of water per pound of fuel. In other words, Professor Denton has demonstrated that in boilers well proportioned and carefully handled 78.5 per cent of the entire calorific value of the oil was made effective. In ordinary practice, without the use of special precautions to guard against waste, 13 pounds of water should be evaporated by 1 pound of Beaumont petroleum, as compared with 6 to 6.5 pounds of water evaporated by the bituminous coals of Indian Territory, 8.7 pounds by Pittsburg coal, and 9 by Pennsylvania anthracite.

COMPARATIVE FUEL VALUE OF COAL AND BEAUMONT PETROLEUM.

The relative fuel value of petroleum and various standard coals may be obtained by comparing the amount of water evaporated by 1 pound of the various fuels. Taking 13 pounds as the amount evaporated by 1 pound of Beaumont petroleum under ordinary conditions, and 6.5 pounds as the amount evaporated by southwestern bituminous coal under similar conditions, the ratio $\frac{13}{6.5}$ is 2. If a better grade of coal is used, the ratio will be smaller. Thus with Pittsburg coal, which evaporates 8.7 pounds of water, the ratio $\frac{13}{8.7}$ would be 1.5.

The average specific gravity of Beaumont petroleum is about 0.921, so that it weighs 7.68 pounds to the gallon, or about 322 pounds to the barrel of 42 gallons.

Taking the first ratio, 2, obtained above from the comparison of the evaporation by Beaumont petroleum and southwestern bituminous coal, it will be seen that 1,000 pounds of petroleum are required to do the work of 1 ton of coal of 2,000 pounds; or, since 1,000 pounds are equivalent to 3.1 barrels, 1 ton of southwestern bituminous coal may be regarded as having the same fuel value as 3.1 barrels of petroleum. The following table gives the value of Beaumont petroleum for steam-raising purposes compared with two standard grades of coal at prices varying from $1 to $7 per ton:

Comparative fuel value of coal and Beaumont petroleum.

Price of south-western coal per ton of 2,000 pounds.	Number of barrels of Beaumont petroleum to equal 1 ton of coal.	Price of Beaumont petroleum per barrel to equal cost of 1 ton of south-western coal.	Price of ordinary Pittsburg coal per ton of 2,000 pounds.	Number of barrels of Beaumont petroleum to equal 1 ton of Pittsburg coal.	Price of Beaumont petroleum per barrel to equal cost of 1 ton of Pittsburg coal.
$1.00	3.1	$0.32	$1.00	4.31	$0.23
1.25	3.1	.40	1.25	4.31	.30
1.50	3.1	.49	1.50	4.31	.35
1.75	3.1	.57	1.75	4.31	.41
2.00	3.1	.65	2.00	4.31	.47
2.50	3.1	.80	2.50	4.31	.58
3.00	3.1	.97	3.00	4.31	.70
3.50	3.1	1.13	3.25	4.31	.83
4.00	3.1	1.29	4.00	4.31	.93
4.50	3.1	1.45	4.50	4.31	1.05
5.00	3.1	1.61	5.00	4.31	1.16
6.00	3.1	1.94	6.00	4.31	1.39
7.00	3.1	2.22	7.00	4.31	1.62

It should be noted, however, that the conditions under which coal and petroleum are used in ordinary practice favor the obtaining of a larger per cent of the theoretical fuel value in the petroleum than in the coal. Also a deduction of at least 10 per cent should ordinarily be made from the fuel cost of petroleum on account of economy in handling the liquid fuel as compared with coal. Additional benefits connected with the use of petroleum are cleanliness, healthfulness, and absence of smoke, which, however, can not easily be estimated in a money equivalent.

It has been urged that the extremely disagreeable odor of the Beaumont oil will militate against its use as a fuel and that in densely settled districts its use will not be permissible. It may be positively stated, however, that when the burners are in good, clean working order no odor whatever can be detected from the burning oil, and when it is used in locomotives the absence of dirt and cinders is the only noticeable feature.

LOCOMOTIVE TESTS.

As a locomotive fuel, petroleum has many additional advantages over coal. Among the more important of these are the perfect control under which it is held and its quick response to the great variations in demand made upon the boiler. Also in the narrow limits of a locomotive firebox the combustion is much more complete with petroleum than with coal, and a correspondingly larger proportion of the theoretical fuel value is utilized. This may amount to as much as 30 per cent added to the efficiency of the boiler. A further great advantage in locomotive use is that it weighs only 67 per cent as much as coal having the same heating capacity.

Practical tests of Beaumont petroleum have been made by the Southern Pacific Railroad and the Gulf, Colorado and Santa Fe Railroad. Both of these roads had already had experience with California petroleum, and were therefore in a position to carry out their experiments in a practical way. According to Mr. Stillman, of the Southern Pacific road, the specific gravity of the oil used was 0.9594 (16° B.). It had a flash point of 240° F. and fire test of 290° F. The results of the test on this road, as compared with coal, are shown in the following table:

Comparative test of petroleum and coal for locomotive fuel.

	Petroleum.	Coal.
Length of run .... miles..	224	224
Average steam pressure .... pounds..	133	130
Water evaporated .... gallons..	6,609	5,980
Oil burned .... do....	755	....
Fuel burned .... pounds..	6,040	8,043
Length of run per ton .... miles..	74.14	55.72
Amount of the two fuels doing the same work	[a] 3.1	[b] 1

[a] Barrels of 42 gallons. [b] Ton of 2,000 pounds.

From this test it appears that with petroleum at 30 cents per barrel, which is somewhat above the market price prevailing at the time the test was made, coal should be worth only 93 cents per ton; or stated in another form, with coal at $3 per ton, petroleum should be worth 97 cents per barrel.

METHODS OF BURNING THE OIL.[a]

Of the numerous styles of oil burners on the market, practically all consist of various modifications of the sprayer. Some of the earlier styles were of a different pattern, but these have been abandoned, The burners now in use all work on the principal of spraying or, as some claim, vaporizing the oil by the use of steam or air under considerable pressure, working somewhat on the style of a Bunsen burner When steam is used it should be taken from the highest part of the boiler and should be dry. It need not be superheated as was at one time considered necessary.

When working properly the flame is a clear white with an intense heat, and as the fuel is completely consumed no smoke issues from the chimney. When perfect combustion is interrupted by a too rapid feed of oil or an insufficient supply of air, an intensely black smoke pours from the stack in great volumes, covering everything it touches with a black greasy soot. Under these conditions the flame becomes a dull red, the oil is not consumed, and, although more fuel is used, less work is performed. When steam is used in excess the smoke is white and watery owing to the condensation of the steam. Under these conditions the fire usually goes out.

In making his experiment Professor Denton used the Williams burner. His arrangements for burning the oil probably represent the best practice yet devised, and, with his modifications of the boiler furnace, are shown in figs. 13 and 14.

Four ducts of hollow tile (F, fig. 14) 10 by 6 inches were laid in the ash pit, extending nearly to the bridge wall, and the ash-pit door openings closed by brickwork around the outer ends of the tile.

The forward bearer of the grate bars (N, fig. 14) was dropped, about half of the forward set of bars removed, and a course of fire brick (O, fig. 14) laid with fire clay over the whole upper surface of the grates, so that air entering through the tile could flow back along the outside of the latter, and then around and up between the front end of the grate bars through an area a little greater than that of the aggregate cross section of the tiles.

A checkerwork (P, fig. 14) of about 50 loose fire brick was built over the grates, the space back of the bridge was filled with ashes (R, fig. 14) flush with the top of the bridge wall, and a single-course floor (Q, fig. 14) of fire brick laid over the ashes.

An iron bar (*a*, fig. 13) was bridged across the middle of the fire-door opening, and the remainder of the latter closed with fire brick (V; figs. 13 and 14) flared on the inside, a small opening (L, fig. 13) being left for applying the torch to the burners. Into the iron bar across each door was screwed the burner (K, fig. 14).

Oil enters the burner vertically through the opening (b, Pl. IX) under control of the cock (c, Pl. IX), regulated by the handle (d, Pl. IX, *A* and *B*).

Steam enters the opening (e, Pl. IX, *A* and *B*) and flows through the conical opening (f), regulated by the hand wheel (g), to meet the oil as the latter falls between the vertical flanges (h, *B*).

A third opening (i, *A* and *B*) in the burner draws air from the back of the furnace through a firebrick duct built on top of the grate and connecting with the bottom side of the latter at its rear, while the front end communicates with the iron pipe (M, fig. 13) connected to both burners.

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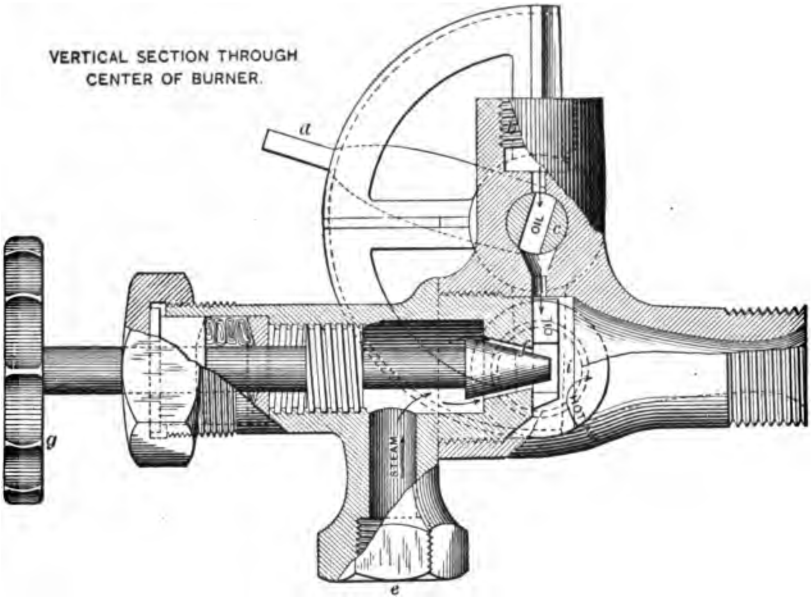
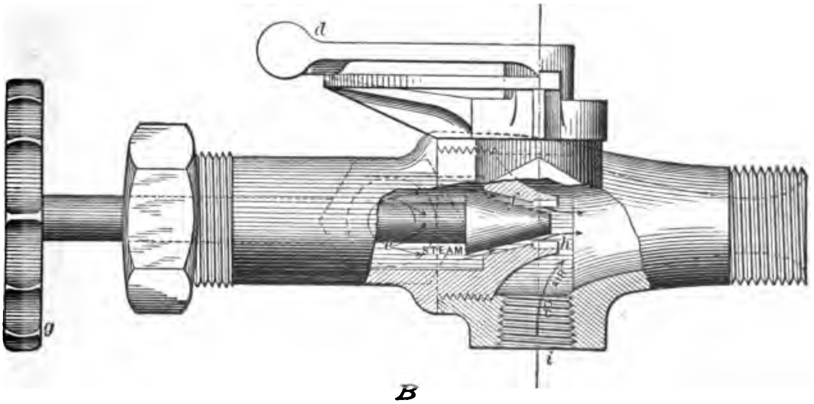
[a] Reprinted from Bull. U. S. Geol. Survey No. 212.



VERTICAL SECTION THROUGH CENTER OF BURNER.

A

HORIZONTAL SECTION THROUGH CENTER OF BURNER.



B

WILLIAMS BURNER.

A mixture of steam, oil, and heated air is therefore blown out of the burner, and this is joined by the main current of air flowing up around the front end of the grate bars, somewhat heated by its passage along the underside of the grate.

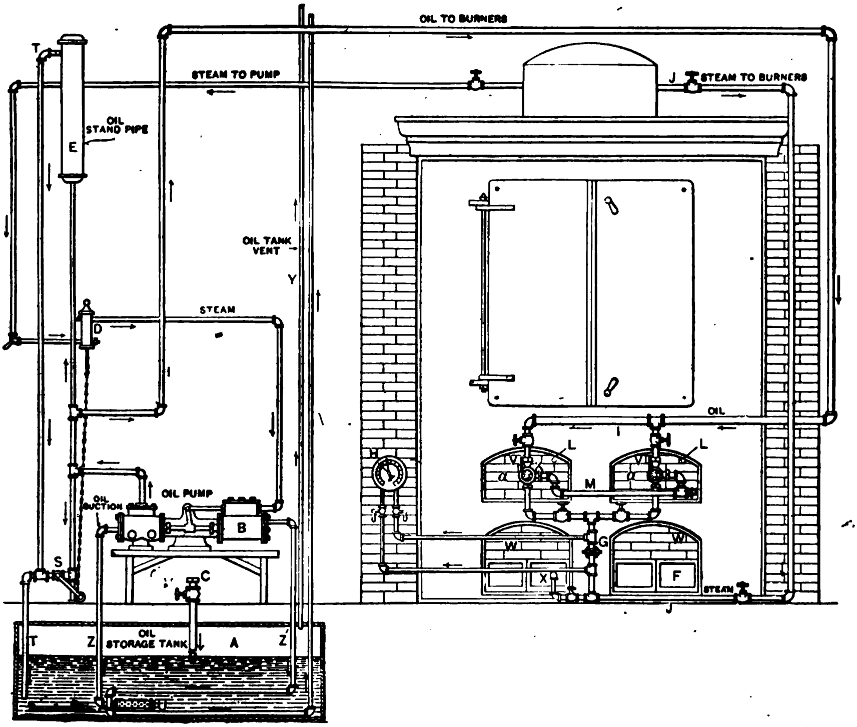


FIG. 13.—Boiler furnace with oil-burning equipment.

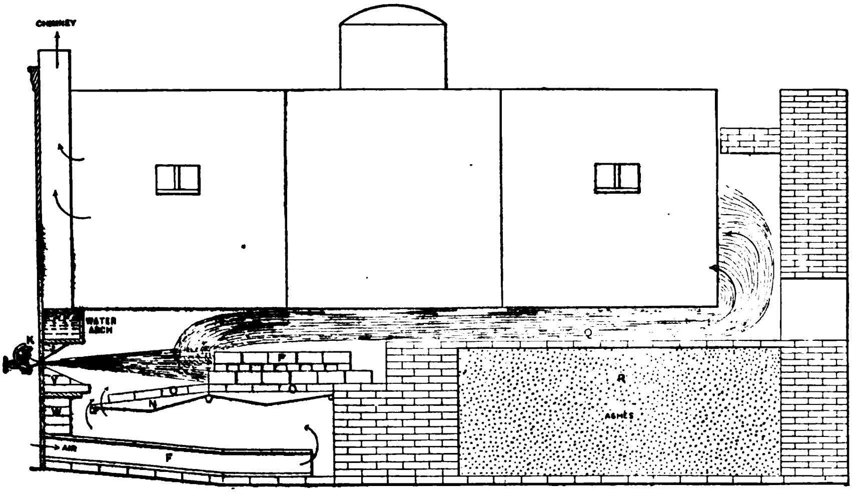


FIG. 14.—Boiler furnace arranged for burning oil.

The oil was stored in an iron tank (A, fig. 13), 7 feet in diameter by 5 feet deep, sunk in the ground, into which the oil is emptied through the pipe (C, fig. 13). The top of the tank was closed, ventilation being afforded by the pipe (Y, fig. 13).

A steam pump (B, fig. 13) drew oil from the tank through the strainer (U, fig. 13) to the burners under a head of about 10 feet.

The pump was run constantly and delivered a surplus, which flowed back to the tank through the pipe (T, fig. 13).

The oil was prepared with a device[a] (D, fig. 13) having a piston connecting by a chain with a cock (S, fig. 13), which automatically opened when the boiler was not under steam pressure, so that the standpipe would be emptied of oil by the latter flowing to the storage tank.

The steam exhaust of the pump passed through the tank by the pipe (Z′, fig. 13) and thence to the atmosphere. Thereby high cold test oil is kept sufficiently fluid in cold weather to flow freely into the strainer, but is not sensibly heated to the touch when it arrives at the burner.

The air entered the ash-pit tiles under the natural draft of the chimney, 70 feet high by 42 inches square, connecting to the boiler tested by a 40-inch flue about 30 feet long.

STORAGE AND TRANSPORTATION.[b]

During the earlier days of the Beaumont field the companies owning wells were seriously handicapped by the want of means of taking care of the oil or sending it to market. The immense quantity produced was unexpected and no one was prepared to handle it. The companies had no tankage, and consequently, although drilling was carried on, and even stimulated beyond all reason, the wells, as soon as determined to be flowing wells, were closed until such times as the owners could make arrangements to dispose of the oil.

The railroad companies were not in a position to furnish cars, and for months looked upon the fields as a sort of freak that would soon die, and they considered themselves hardly justified in the purchase of new cars to supply the demand. These roads delayed action until several of the larger and wealthier companies commenced purchasing individual cars and shipping in that way. These companies own over 1,000 cars, and the railroads are now supplying enough additional cars to meet the demand.

[Pipe lines were laid to the coast at Port Arthur and Sabine Pass, and shipments by water were made from these ports. At the close of 1904 there were four pipe lines from Spindletop to Port Arthur, three to Sabine Pass, and not less than five to Sour Lake. There were also four lines from Saratoga to Sour Lake, two from Batson to Sour Lake, and not less than four between Batson and Saratoga, besides several pipe lines connecting the fields with the railroads at different points. After the opening of the Humble field various pipe lines were built connecting it with Houston on the south and Batson on the east. The Dayton field is reached by the lines between Humble and Batson. The oil from Jennings, La., is conveyed by three pipe lines to as many different points on the Southern Pacific Railroad or by other lines to the bayous, where it is loaded on barges to be taken to the rice-farm irrigating plants to be used as fuel for pumping. A fourth pipe line connects the Jennings and Ause la Butte fields with a port on Atchafalaya River. The water shipments are mostly coastwise to New Orleans, Baltimore, New York, and other coast harbors. Considerable quantities are also shipped to European ports by the Shell Transport and Trading Company, which has two steam tank ships of 60,000 barrels capacity in the trade regularly.

The tankage in the field to the close of 1904 amounted to about 30,000,000 barrels. The larger part of this is in earthen reservoirs which have been found fairly satisfactory and much cheaper than steel tanks.] * * * Some of these earthen tanks have nothing done to them beyond excavating to the required depth; others are lined with timber, and while some of them are open, others are covered with a light board roof.

The capacity of the steel tanks ranges from 10,000 to 55,000 barrels, while the earthen tanks range from 25,000 to 350,000 barrels.

For fire protection the steel tanks are surrounded by a moat and embankment, giving a storage capacity equal to the full content of the tank.

METHODS AND COST OF WELL DRILLING.[b]

ROTARY METHOD.

The rotary method of drilling is the one used almost exclusively in the Gulf Coastal Plain oil fields. This appears to be a modification of the Fauvelle system, invented in 1845, and used for some time in several of the European oil fields. It is unquestionably the most rapid and economical method where the formations to be penetrated are for the most part unconsolidated. The vast amount of drilling done in this field since the spring of 1901 and the keen competition among the drillers has brought the method and machinery to a high state of efficiency.

The rotary is so entirely different from the old-fashioned cable rig and churn drill that it has been thought desirable to insert a brief account of the machinery and method.

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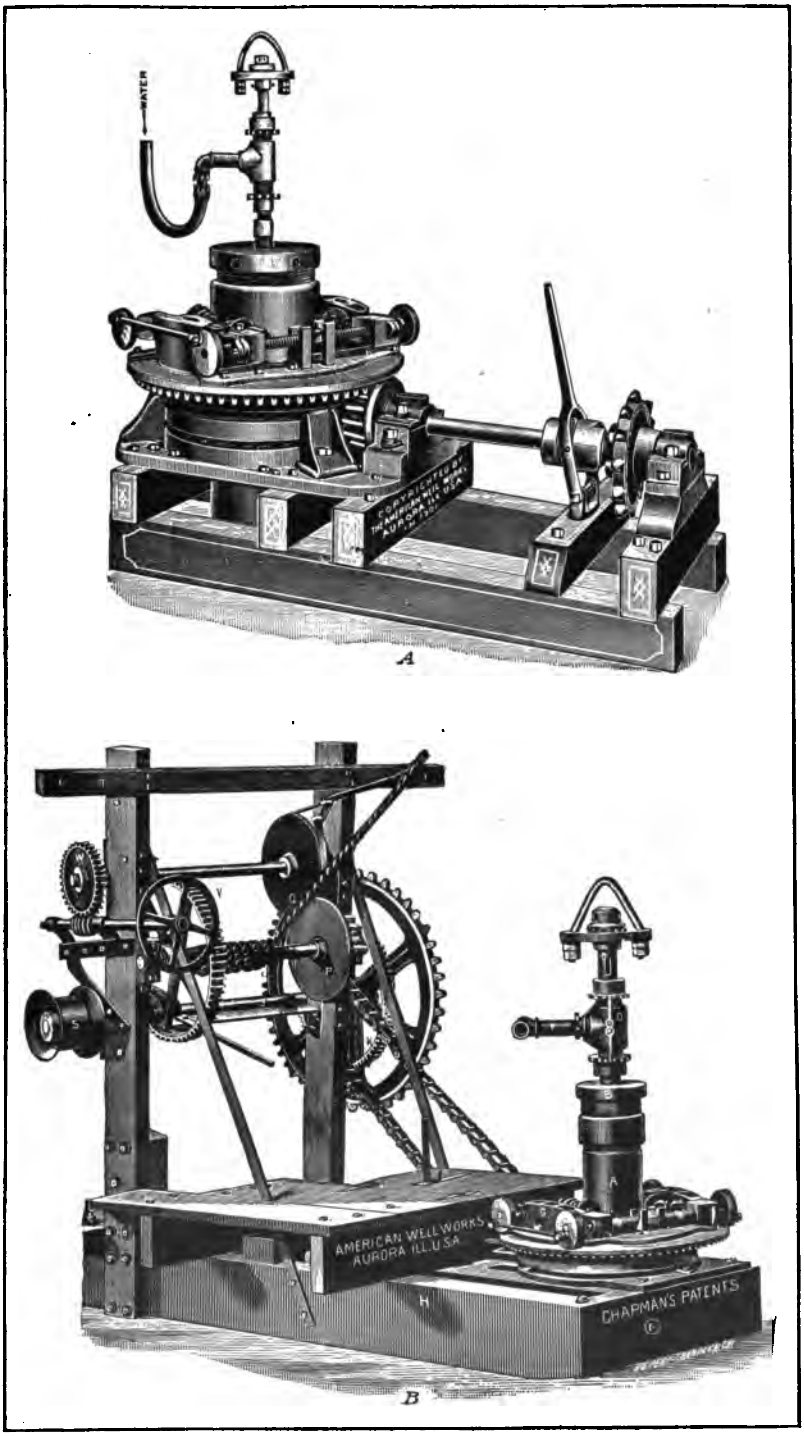
[a] There is a safety device required by western insurance rules.

[b] Reprinted with slight revision from Bull. U. S. Geol. Survey No. 212.



A. CHAPMAN ROTARY DRILL.
B. HOISTING AND OPERATING MACHINERY.

MACHINERY AND OPERATION.

There are three styles of rotary drill in the field, differing slightly in details, but all working on the same principle. The form in most common use, the Chapman patent, has been taken for illustration. A general view of the derrick with machinery in place is shown in fig. 15, the rotary in Pl. X, *A*, and the hoisting and operating machinery in Pl. X, *B*.

The method consists essentially in rotating a vertical drill rod, through which a continuous stream of water is forced downward. The drill rod is supported by a cable passing from a hoisting drum over a pulley at the top of the derrick and thence by block and fall to a swivel attached to the top of the drill rod, the descent of the latter being controlled by the driller by means of a feeding device. The lower end of the drill rod is supplied with one of several forms of bit, adapted to the kind of material being drilled. The material loosened by the rotating bit is carried upward to the surface by the water ascending on the outside. This ascending current of water keeps the hole clean and allows the drill rod to turn freely. It is essential that the flow of water should be continuous, and a drilling outfit is always supplied with two force pumps in order to avoid any danger of stopping the flow. If the well has passed through a pervious stratum, such as a bed of loose sand, the ascending water is liable to pass into that stratum instead of returning to the surface. This quickly results in the clogging of the hole, and in order to prevent it the water which is pumped in is mixed with a large amount of fine clay. By this means the outlets through porous beds are sealed up, the unconsolidated material forming the walls of the hole is prevented from caving, and the water returns unimpeded to the surface. [The occasional failure to obtain a return current is discussed on page 122.]

The forms of bits most commonly used are shown in Pl. XI, *A*, *B*, *C*. The fishtail bit (*A*) is adapted to soft materials, such as sand and clay. The core-barrel bit (*B*) is better adapted for harder materials, such as very compact clay, indurated sand, etc. Where rock is encountered the ordinary bits make very slow progress, and the drilling is greatly facilitated by the use of the adamantine, or shot, drill, the cutting being done by a quantity of steel shot which revolve under the rim of the tube (*C*). Some drillers, in passing through hard rock, rig up a regular churn drill, the cable passing over a pulley at the top of the derrick and thence down to the engine fly wheel, where a turn around the crank pin gives the required lifting-and-dropping motion to the drill.

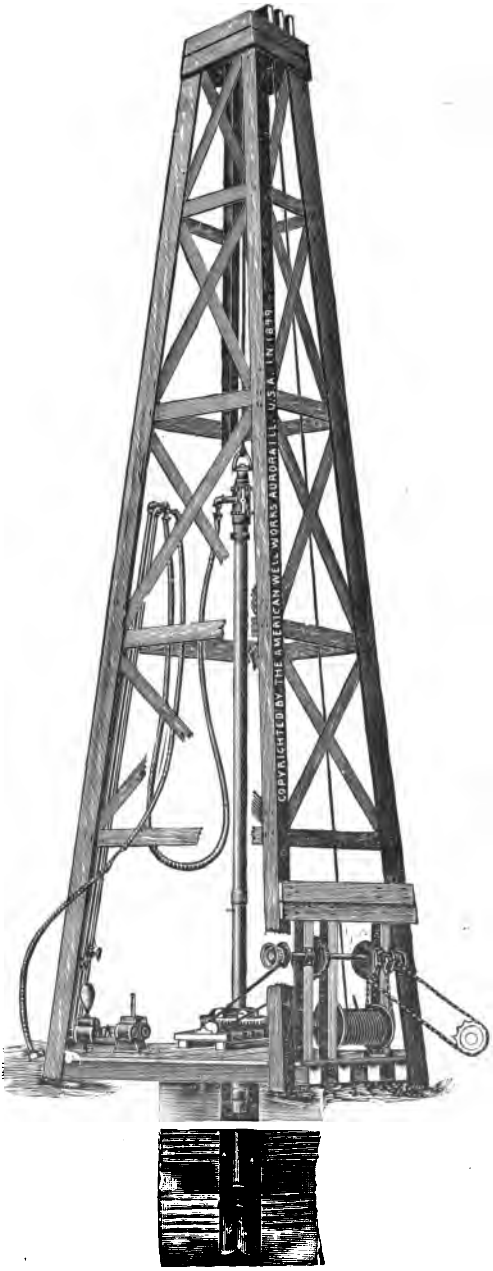

COPYRIGHTED BY THE AMERICAN WELL WORKS AURORA ILL. U.S.A. IN 1899

FIG. 15.—Derrick with machinery in place.

When everything is ready to begin operations a length of rod with the bit attached is made fast to the water swivel and lifted into the derrick. The bit and lower end of the rod are passed through the rotary far enough to allow the jaws to be brought together and clamped so as to hold the drill rod and rotate it. The driller starts the engine and sets the pump in motion. As soon as the water flows freely he slackens the friction and allows the drill to descend.

The force of water, which varies from 40 pounds to 75 or 80 pounds, passing through the rod finds its way as jets through two holes, one on either side of the fishtail bit, and washes the freshly loosened sand up to the surface through the space between the drill rod and the wall of the well. As the work progresses the driller lowers the rod slowly, holding it stationary or letting it descend, according to the character of the material through which the bit is working. From this time on the whole responsibility rests upon the judgment of the driller. The drilling crew generally consists of four men—the driller, two derrick men, and the fireman—with a corresponding night shift, as the work proceeds night and day.

The work progresses rapidly at first, but becomes slower as the drill goes downward. Great care is required to keep the drill in motion and a sufficient supply of water passing-through, as a stoppage for a short time often "sticks" the work, and considerable time is lost, as the rods and often the casing already in place have to be withdrawn from the well.

In starting a well arrangements are generally made for the insertion of a 12-inch casing to begin with, and in boring for this size the drill rods are generally made of 6-inch casing with a 13½-inch bit. This sized bit is used to allow the collars at the joints of the 12-inch casing to slide past without damaging the wall of the well. The length of 12-inch casing used varies from 500 to 800 feet, depending largely upon the nature of the ground and the skill of the driller. The hole is generally left open until the whole depth calculated for one string of casing has been drilled. This generally extends until a hard stratum is met with, upon which the casing to this depth may stand. When the depth has been reached, the drill is withdrawn and the casing set.

Following the 12-inch casing the hole is next drilled for an 8-inch or 9-inch casing. In either case a 10½-inch bit is used. This 9-inch casing has in several of the Spindletop wells been placed in the oil sand. After setting the 9-inch casing the drilling proceeds downward with a 6-inch casing. Occasionally a still further reduction to a 4-inch or even 2-inch becomes necessary.

COST OF DRILLING.

The drilling of the well is usually carried on by contract. Some few of the companies own their own outfits and drill on the company's account. During the earlier period of the history of the field several of the companies bought drilling outfits and erected the derricks. When new companies were rapidly springing up, it was usual to find the companies investing money in drilling machinery, and the alluring sentence that the work had actually been begun on the company's holdings "by the erection of a derrick" appears in many of the prospectuses issued at that time. This was chiefly for the purpose of inducing people to buy stock. At that time it was also the rule of the company to provide the casing, the contractor finding the tools and doing the work. Later the contractor was generally required to furnish everything and turn over the well to the company upon its completion. The contract in proved territory usually calls for a specified depth, or a good flowing well if found at a less depth.

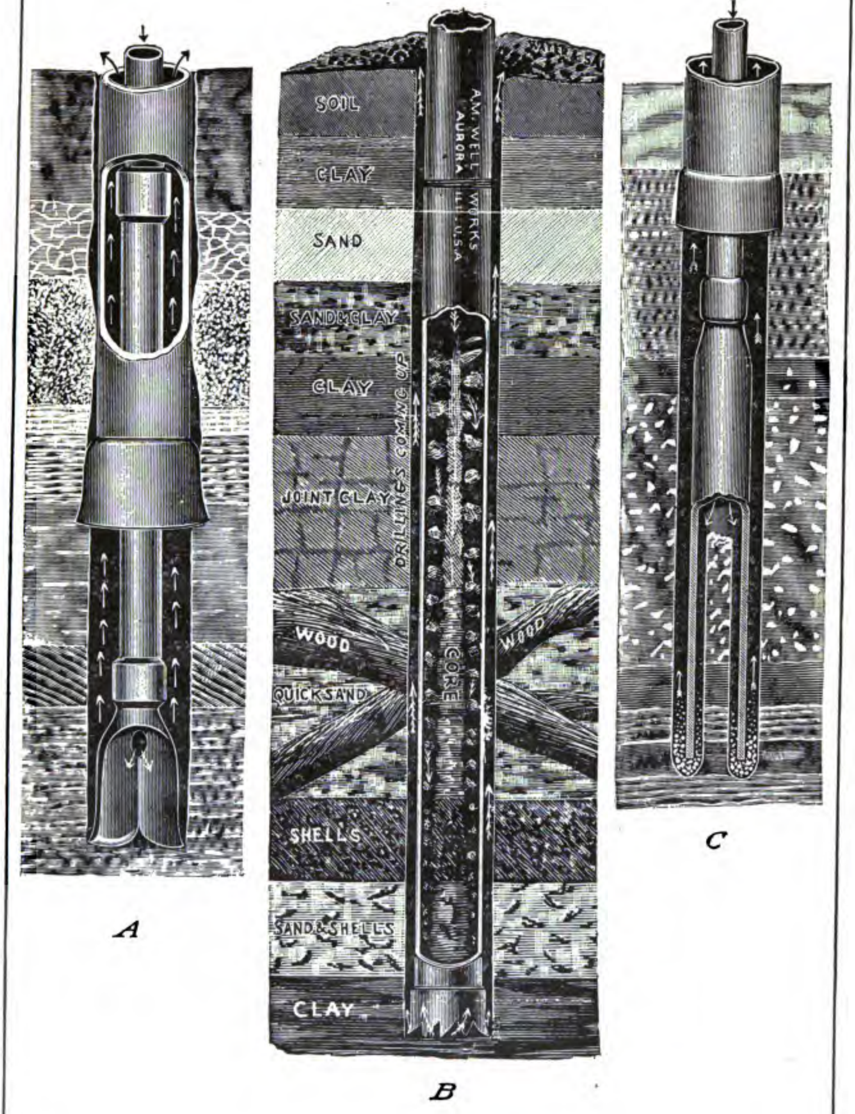
Prices vary in accordance with the conditions of the contract, but from $4 to $4.50 per foot may be considered as a fair average of prices at Beaumont after the early excitement had subsided, the contractor furnishing all machinery, tools, labor, etc., necessary to drill the well. The company usually reserved the right to accept or reject the work upon completion.

The average time required to drill a well in any of the oil fields when no accident occurs is about two months. Several wells on Spindletop have been drilled in less than one month, but the greater number of them have occupied between two and three months. The work is often kept up night and day, though most of the contractors are content to keep the pumps at work all night without attempting to drill.

FINISHING THE WELL.

When the well approaches completion, the drill rods are withdrawn and a gate valve fitted to the casing in such a way as to permit a rapid closing of the well if desired. When the valve is in position, the bit is again lowered and the work proceeds until the oil sands have been reached and penetrated to a sufficient depth to insure a flow in the well. The drilling tools are then withdrawn, the water bailed, and the well allowed to flow. When a sufficient time has elapsed to allow of the well cleaning itself of all loose pieces of rock or gravel, the valve is closed and the well shut in. None of these wells has been torpedoed. This method of inducing a flow was tried in one case on Spindletop and the only result was a ruined well.

NOTE.—In November, 1905, the Mound Oil Company completed a successful well not far from the drillings described under "Hoskins Mound" on page 86. By unusual precautions this success was secreted for five months, the well being capped and allowed to flow only enough oil to supply fuel for drilling other wells. On the basis of these short-time flows it has been reported that the well would produce 2,500 barrels daily. The well is 582 feet deep and is said to be finished in "rock" which it penetrated a few feet but did not pass through. As no strainer was used it is not improbable that the oil comes from a porous limestone. The oil is said to be of a green color and exceptionally low in sulphur. Its gravity is 21.5. It is hoped that since the entire mound is in the hands of one company composed of experienced oil men the new field will not be "Spindletopped," or wastefully exploited.



A. FISH-TAIL BIT.
B. CORE-BARREL BIT.
C. ADAMANTINE OR SHORT DRILL.

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[Bulletin No. 282.]

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